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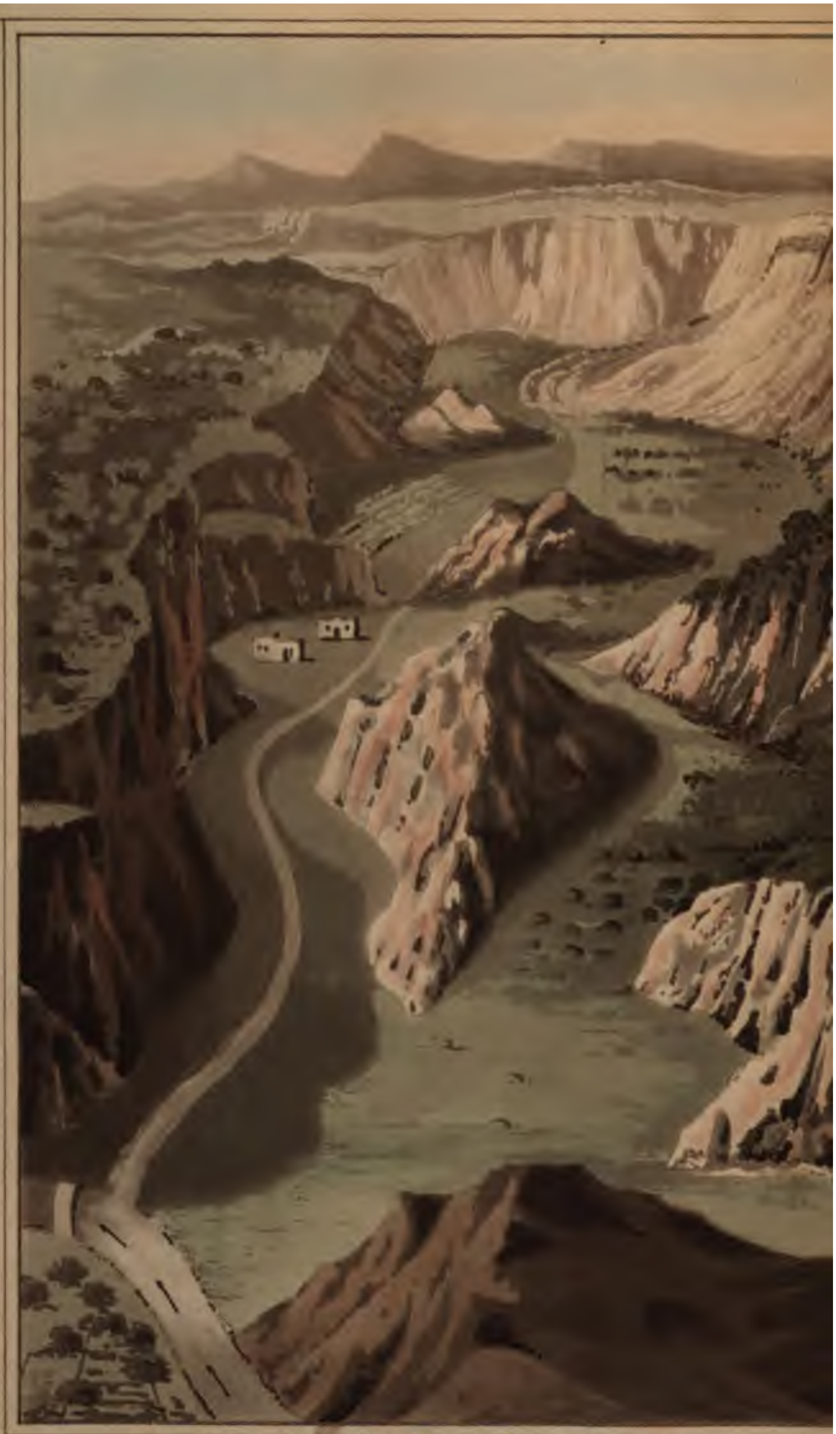

Published by John Harding, St. James's Street, March 1815.

Salt Formation at Cardona in Spain.

AN

INTRODUCTION

TO

GEOLOGY,

ILLUSTRATIVE OF

THE GENERAL *STRUCTURE OF THE EARTH;*

COMPRISING

THE ELEMENTS OF THE SCIENCE,

AND AN OUTLINE OF THE GEOLOGY AND MINERAL
GEOGRAPHY OF ENGLAND:

BY ROBERT BAKEWELL.

THE SECOND EDITION CONSIDERABLY ENLARGED.

> "A knowledge of our subterranean wealth would be the means of furnishing greater opulence to the country than the acquisition of the mines of Mexico and Peru." *President of the Board of Agriculture.*

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PREFACE TO THE FIRST EDITION.

In tracing the progress of knowledge, we may frequently observe that the cultivation of particular branches of science at certain periods was determined by causes which had little connection with their intrinsic utility. Fashion, caprice, and the authority of eminent names, govern mankind in philosophy as well as on all other subjects. But, independently of accidental causes, there are leading objects in the universe, which, as nations advance in civilization, seem naturally to direct their attention to certain sciences in succession. The brilliancy of the sun, moon, and planets, their various motions, and connection with the changing seasons, would first arrest the attention of the rude philosopher; nor need we wonder that he soon began to regard them as endowed with life and intelligence, and attributed to them a mysterious power over human affairs: thus the heavenly orbs became the objects of religious adoration; and curiosity, hope, and fear, lent their aid to the early cultivation of astronomy.

Mathematics and mechanical philosophy are so intimately connected with astronomy and the most useful arts, that they naturally claimed the second place among the early sciences.

The branches of philosophy which comprise a knowledge of the physical qualities of matter, or such as are perceptible by the senses, follow next; and at a later period chemical philosophy, or that science which endeavours to ascertain the elementary substances of which all material objects are composed. In the order of succession, mineralogy and geology are the last of the natural sciences; for though an acquaintance with the earth is more important to man than a knowledge of the distant parts of the universe, yet previously to the cultivation of the other sciences, and of chemistry in particular, our knowledge of the mineral kingdom could not extend much beyond that of the rudest periods. Thus we find that notwithstanding the precious metals, and many of the mineral treasures which the earth contains, have been the objects of insatiable cupidity in every age, yet, till the present day, almost all that was known of mineralogy was confined to uneducated working miners.

In looking over the pages of history, we may observe that the most polished nations of antiquity had scarcely advanced beyond a limited acquaintance with astronomy, geometry, and mechanical philosophy. In modern Europe, all the natural sciences, geology and mineralogy excepted, have been successfully cultivated, and their progress has been astonishingly rapid; but till about the middle of the last century the structure of the earth had scarcely engaged the attention of philosophers. Near that time, Lehman, the German, first observed that there are certain rocks which occupy the lowest relative situation in different countries, and that these rocks contain no organic remains: hence he gave them the name of primary, and established a division between them and the rocks by which they are covered, in which the remains of animals or vegetables frequently occur: the latter he called secondary. In our own country, the Reverend J. Michell was the first person who appears to have had any clear views respecting the structure of the external parts of the earth: they were made public in a valuable paper on the cause of earthquakes in the Philosophical Transactions, 1759. About twenty years afterwards, Mr. John Whitehurst published his "Inquiry into the original State and Formation of the Earth." His observations were principally confined to the rocks and strata of Derbyshire. Independently of its speculative opinions, this work was highly valuable, as an attempt to describe the geology of a district from actual examination. The great variety of original information it contained, and its general accuracy, will remain a lasting monument of the writer's industry and ability. Mr. Whitehurst, however, fell into the same error with the celebrated Werner in Saxony, an error to which the first cultivators of geology were particularly exposed, that of drawing general conclusions from local observations, and forming universal theories from a limited number of facts.

Though Mr. Whitehurst's book was favourably received, yet till the beginning of the present century geological pursuits made little progress in England. On the continent, the researches of Saussure, Pallas, Werner, St. Fond, Dolomieu, and others, had before this time produced a powerful interest, and brought into the field many active and enlightened inquirers. The first general impulse given to the public taste for geological investigations in this country was produced by Professor Playfair's luminous and eloquent illustrations of the Huttonian theory. The leading feature of this theory, that all rocks or strata have been either formed or consolidated by central subterranean fire, was ably and very warmly opposed; and much personal animosity and many adventitious circumstances were associated with the contest, not highly honourable to philosophy, but well calculated to keep alive the attention of the disputants to those appearances in nature which favoured or opposed their different theories.

The interest excited by the brilliant discoveries lately made in chemistry has accelerated the progress of geology, by developing new views respecting the objects in the mineral kingdom, and creating a desire to be acquainted with the situations in which they occur. Hence a taste for such inquiries is more prevalent among the intelligent classes of society in this country than at any former period; and in the course of my professional pursuits, and the geological lectures I have occasionally delivered, I have repeatedly heard the want of an intelligible introductory treatise on geology much regretted, by persons who lamented their inability to comprehend the 'Geognosy' of Mr. Jameson, and their equal inaptitude of attention to the polemical controversies of M. De Luc. To both these gentlemen geology is under considerable obligations; and if their elementary works have failed in exciting general interest, it is owing, I conceive, to an over-strained attachment to their particular theories, or to the technical obscurity in which those theories are involved *.

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* Mr. Kirwan may be justly regarded as the father of British Mineralogy: but he appears never to have studied geology out of his own cabinet; for though Dublin, where he resided, is more favourably situated for geological inquiries than perhaps any other capital in Europe, he considered the interesting rock formations in its vicinity as objects far too sacred to be explored, except by German eyes. The Dublin Society, in conformity with his example, have recently

He who attempts to make a scientific subject familiar, runs the risque in this country of being deemed superficial: a plentiful share of dullness, combined with a certain degree of technical precision, are regarded as essential proofs of profundity. By prescriptive right long established in these realms, dullness and pedantry guard the portals of the temple of Science, and command those who enter, to avert their eyes from whatever can elevate the imagination, or warm the heart, and to look at nature through a sheet of ice. In compliance with their authority, writers of introductory treatises have generally thought it necessary to avoid that felicity in the familiar illustration of scientific subjects so conspicuous in some of the elementary works of our neighbours. Without venturing to depart too far from established usage, I have endeavoured to render geology more intelligible, by avoiding as much as possible theoretical and technical language, and by introducing a simple arrangement suited to the present state of our knowledge. The local illustrations from various parts of our island, with the drawings, sections, and map in the present volume, will I trust facilitate the study of geology, and prove par-

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recently elected a German Mineralogist for the *avowed* purpose of delivering public lectures on Geology, disregarding the trifling inconvenience of his being an utter stranger to the English or Irish languages.

ticularly acceptable to those who are entering on these inquiries; at the same time, I flatter myself with the hope, that the original information this work contains respecting the geology and natural history of England, will secure it a candid reception.

Several have been deterred from the study of geology by the supposed difficulty of learning its attendant science, mineralogy; but an acquaintance with the nice distinctions made by many modern mineralogists is not necessary to gain a knowledge of the structure and arrangement of the great masses of matter that environ the globe, nor of the substances of which they are composed. The number of simple minerals which form rocks and strata is small; and when the student is well acquainted with their physical and chemical properties, their external characters, and more common modes of intermixture and combination, he is prepared to commence an examination of nature for himself with satisfaction and advantage. The pedantic nomenclature and frivolous distinctions recently introduced into mineralogy, may gratify vanity with a parade of knowledge; but they are unconnected with objects of real utility, or with any enlarged views of nature.

On hearing the various names which mineralogists give to the same substance, and observing the avidity with which each new name is seized, as if it conveyed a hidden charm, the uninitiated might suppose that he was "journeying in the land of Shinar," and had fallen in company with a set of masons fresh from the tower of Babel, each one calling the same stone by a different name, and glorying in his absurdity. Such frivolities disgust men of sense with the study of an important and interesting science, a science that has for its immediate object the structure of the planet which the Author of nature has destined for our abode, and an acquaintance with the situation of its various mineral productions, subservient to the wants or enjoyments of man in civilized society.

The advice of Cicero to the cultivators of moral science applies with peculiar force to the geologists and mineralogists of the present day. 'In these natural and laudable pursuits, two errors are particularly to be avoided: the first, not to confound those things of which we are ignorant with those we know, or rashly to yield our assent without due investigation; the second, not to bestow too much labour and study on obscure, intricate, and unprofitable subjects.' 'In hoc genere et naturali et honesto duo vitia vitanda sunt: unum, ne incognita pro cognitis habeamus, hisque temere assentiamur (quod vitium effugere qui volet adhibebit ad considerandas res et tempus et diligentiam). Alterum est vitium, quod quidam nimis magnum studium multamque operam in res obscuras atque difficiles conferunt, easdemque non necessarias.'—Cic. Offic. i. 6.

PREFACE

TO

THE SECOND EDITION.

FROM the speedy sale of the first edition of the Introduction to Geology without any assistance from the patronage or early notice of the literary journals and reviews, it may be presumed that the work was favourably received. I am therefore encouraged to publish a second enlarged edition under circumstances, in some respects, more favourable to its success.

A person unconnected with public societies, whose name is undecorated with any appendages, has certain difficulties to encounter when he first presents a book on any science to the world. Many even of the learned vulgar, whose minds, as Locke* expresses it, are " confined in a little Goshen of their own," are very unwilling to believe that any knowledge or information can exist beyond the precincts of those establishments or societies with which they are acquainted. The following incident may illustrate the truth of this remark. Soon after the appearance of the first edition, a gentleman placed the book in the hand of a learned and reverend professor in one of our English Universities, accompanied with the inquiry, 'Have you seen this book, sir?'—'Yes, I have.'—'Pray what do you think of it?'—'*G—d! I don't know, but I wonder where the devil he got his information!*' was the reply. Though the answer may sound unclerical to English ears, I am willing to believe that it is conformable to the legitimate modes of figurative expression and the strictest rules of *poetical* propriety,—rules with which *this reverend professor is of course* so familiar. Men of more enlarged minds are ever ready to hail the progress of information, without stopping to inquire whether it be given by a titled or untitled individual. A distinguished ornament of the other university, a prelate whose name will long be dear to science, to learning, and religion, the venerable bishop of Landaff, rose, as he expressed it, immediately from the reading of my book to lose no time in communicating his approbation to the author; a testimony the more flattering, as it was given without *any previous* communication or acquaintance with his lordship; and still more gratifying, as it was from the early perusal of his lordship's Chemical Essays that I first acquired a taste for these pursuits. These essays, amidst the changing language of theory, will ever remain a valuable record of facts, and serve as a perfect model for a just philosophical style; learned without pedantry, definite without technical obscurity, at once simple, elegant, and perspicuous. To return to my professor: Should he honour the present edition with his perusal, I trust he will find in it additional information, and that he may not again invoke supernatural agency to reveal the means by which it was acquired, the case being *haud dignus vindice nodus*, not of sufficient difficulty to require such assistance; I shall briefly acquaint him with the secret. Since the first appearance of the work, I have travelled over two thousand miles of the United Kingdom, and had an opportunity of revisiting some of the districts before described, and of examining others I had not then seen. I have also taken a short view of the rock-formations in the west of Anglesea, and the opposite coast of Ireland. From gentlemen residing in the country, who had perused the book, I have received some information and corrections, and I have not been inattentive to the more important observations and discoveries of other geologists in our country or on the continent.

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* Conduct of the Human Understanding.

In the present edition I have ventured to advance some opinions respecting the process of rock-formations, which I am inclined to flatter myself will show that various apparently contradictory or anomalous facts are referable to one general cause, and that some of the difficulties under which geology has hitherto laboured, admit of a satisfactory explanation.

planation. These speculations being proposed as queries, and their truth or probability submitted to their accordance with existing appearances on the surface of our planet, I trust they will be received with indulgence.

In an introductory work, the entire departure from language hitherto received by geologists would be attended with much inconvenience; I have therefore retained the terms primary, transition, &c. though I am convinced that recent observations show more and more their impropriety, when taken in their strict original sense. If, however, by primary countries we mean to designate those in which granite, gneiss, and mica-slate predominate, without any reference to theory; and by transition countries, those abounding in metalliferous limestone or in rocks allied to slate, the terms can occasion no error, and we thereby avoid prolixity of description. The great mistake was in fixing these terms as the expression of invariable natural characters, and in asserting that the same succession of rocks that occurs in Saxony, which Werner first described, exists, or once existed, in every part of the world. Since the universal evidence of facts in other countries made the Wernerian arrangement no longer tenable, there has been such shuffling and shifting of rocks from one class to another, that it threatened to upset the whole surface of the globe, to the no small terror of its inhabitants,

habitants, had they been apprised of the danger. A disciple of Werner has lately ventured to anticipate that the Professor may find it convenient to let some of his universal formations 'slip out of his system.' For the consolation of the timid, we may venture to predict, that when these universal rock-formations pass away, the shock will occasion no catastrophe to our planet, as they never had any existence in nature. The advocates of this system, instead of acknowledging the fundamental error of the first arrangement, imitate the physician of Moliere, who placed the heart of his patient on the right side and the liver on the left, and when reminded by the father that the reverse was believed to be the fact, replied, '*Ah! oui, c'étoit ainsi autrefois, mais aujourd'hui nous avons changé tout celà.*—"It used to be so formerly, but at present we have changed all that*." If philosophers would turn their eyes more upon nature, and think less of artificial classifications, they might not describe their observations with such a technical parade of knowledge, but they would mark more distinctly those natural characters and circumstances that escape the eyes of common observers, but which lead directly to the most valuable discoveries.

It has been urged as an objection to the cultivation of geology, that the phænomena of which it proposes to treat, lead us back for their explanations to periods of time of which we have no historic records; and the objects of present research being buried under the surface, our conclusions are obscured by uncertainty. Objections of equal validity might be advanced against all the other sciences. In chemistry, the very existence of its most important agent caloric, or heat, as a specific substance, is denied by some very eminent philosophers; nor have we, perhaps, better evidence for the existence of oxygen, azote, or hydrogen, as simple elementary substances. In mechanics, the important question of the ratio between the velocity and momentum is still undecided. Even in pure mathematics, where the light of truth is supposed to shine with unclouded splendour, some of the very first definitions are exposed to objections which the most vigorous minds have not been able to remove, and demonstrations of elementary propositions admitted by mathematicians for two thousand years, are now found to be defective or erroneous*. The more abstract speculations on space, time, and matter, have engaged and exhausted the highest intellects of ancient and modern times; yet the mysterious veil is still unremoved, and the only benefit resulting from these inquiries has been to exercise, and in some degree to fix limits to, the powers of the human mind. Are we hence to neglect the cultivation of science? Because we cannot always bask in the blaze of meridian day, shall we close our eyes and sit in darkness indulging "a sullenness against nature?" There are, indeed, few subjects on which we can acquire demonstrative proof; yet our faculties are so constituted, in relation to external objects, that we are able to obtain a high degree of probability sufficient for all useful purposes. The geologist cannot lay open the internal structure of the globe, nor penetrate very far beneath its surface; but what is within his reach is sufficiently interesting and valuable to arrest our profound attention. In the short space of time that geology has been cultivated, perhaps no science was ever more rich in astonishing discoveries; discoveries which have opened the volume of Nature, where the history of the primæval inhabitants of the globe is imprinted in legible characters. I have spoken elsewhere of the immediate utility of geological researches, as disclosing the various treasures of the mineral kingdom. At a time when it becomes so necessary that we should avail ourselves of our natural resources, a work which proposes more immediately to direct the attention of my countrymen to the mineral repositories of Great Britain may claim their indulgence and patronage. The difficulties which have been unnecessarily created in mineralogy and geology, by multiplying names to designate the same mineral substance, and by frivolous subdivisions of species, have more than any other cause retarded the progress of these sciences. Unfortunately, books alone cannot make the student acquainted with minerals: they may teach him what a substance is not; but they will seldom enable him to say what it is, unless he be previously familiarized with specimens.

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* Le Médecin malgrè lui.

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* See Playfair's Geometry, notes on book vii. prop. 20; and Simpson's Euclid, notes on book xi. def. 10.

The external characters of minerals are sometimes too evanescent to be fixed by language, and it is only by frequent inspection that the eye can be *habituated* to detect them: hence this kind of knowledge is in some degree empirical, and hence may arise that kind of pedantic conceit said to characterize many who think themselves *accomplished mineralogists*. It might serve to abate this supercilious self-complacency, were it more generally known that the knowledge on which it is founded, requires less comprehension of mind, and less labour of thought, than are necessary for the attainment of the humblest mechanic art. A steady eye and free access to well-arranged mineral collections are all the requisites for forming an expert mineralogist, whatever may be the range of his intellectual powers.

In making these observations I by no means wish to undervalue mineralogy; the knowledge of it is absolutely necessary to the geologist, and highly useful for various purposes of life; but it is not the less useful for being easy of attainment. I object to what Sir Humphry Davy (in his Lectures) very properly called "barricading the avenues to knowledge from general access by a fortification of hard words and frivolous distinctions." In no department of science has this sin against good taste been so frequently and remorselessly committed, as in that of mineralogy.

Crystallography more properly belongs to the higher branches of physics: the laws of crystallization, explained by the ingenious labours of De Lille and Haüy, have enlarged our views of some of the more refined operations of nature, and have disclosed a marvellous system of geometrical arrangement, extending to the minutest particles of matter, not less regular than the laws which govern the planetary motions. The practical mineralogist can, however, rarely apply the angular measurement of crystals to the examination of minerals in nature, because few of them comparatively are found in a perfect crystalline state.

He who would gain a useful knowledge of mineralogy, would do well to provide himself with specimens of simple minerals and of the different common rocks, and examine their external characters and physical properties, comparing them with the descriptions given by the best mineralogical writers. Fortunately these substances are not very numerous, and he may without present inconvenience omit the more rare crystallizations and varieties so much valued by cabinet philosophers: for here, as in many other instances, the received value is in an inverse ratio to the utility. Considering the great benefits which mankind in civilised society receive from the mineral kingdom, it is truly astonishing that so little attention has been paid to mineralogy or geology until nearly the present time. It is not my intention to dwell on the advantages to be derived from the practical application of these sciences to the improvement of landed property, I beg leave to refer to the notice on this subject, page 454.

The value of every science must ultimately rest on its utility; but in making the estimate we ought not to be guided alone by the narrow views of immediate gain. The objects of nature appear destined to answer two purposes; the one, to supply the physical wants of the various inhabitants of the globe; and the other, to excite our curiosity, and stimulate our intellectual powers to the discovery of those laws by which all the successive changes in the material universe are governed. Were it not for this intellectual excitement, man would be little advanced above the beasts of the forest. In those sciences which have reached the greatest perfection, the contrivance of the Divine Artist, and the ends and uses of the various parts, are most apparent. Geology has not yet made sufficient progress to carry us far in this path of inquiry; but we can already discover that the very disorder in which the surface of the globe is apparently thrown, and the inequalities which it presents, are absolutely necessary to its habitable condition:—the distribution of its mineral treasures, particularly of coal to the colder regions of the globe, is also well deserving our attention; but a cold-hearted philosophy, under the sanction of a quaint expression of Lord Bacon *, has (to use the words of Dugald Stewart) " made it fashionable to omit the consideration of final causes entirely, as inconsistent with the acknowledged rules of sound philosophising. The effect of this has been to divest the study of nature of its most attractive charms, and to sacrifice to a false idea of logical rigour all the moral impressions and pleasures which physical knowledge is fitted to yield."

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* The sentence which condemns the inquiry after final causes as a barren study, is one of those puerile witticisms so common with the writers of Lord Bacon's time, and would have been deemed unworthy of notice had it occurred in the works of any of his cotemporaries. " Causarum finalium inquisitio sterilis est, et tanquam virgo Deo consecrata nihil parit."

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ERRATA.

Page 54, line 5, from the bottom, *for* Kamerni *read* Kamenoi.
82, *for* the Gneiss *read* the nature of Gneiss
109, *for* Gerdal-Sear *read* Gordale-Scar, and *for* Weathercock cave *read* Weathercoat Cove.
352, line 18, after magnesian lime-stone dele (;), and place a period after coal strata, line 19.
382, note, *for* slate of Sicily *read* state of Sicily.
416, line 14, *for* in reality *read* are in reality

INTRODUCTION

TO

GEOLOGY.

CHAPTER I.

Objects of the Science denominated Geology.—The Shape of the Earth and other Planets affected by the respective Velocities of their rotatory Motions.—Density of the Earth.—Theoretical Division and Classification of Rocks.—Arrangement of the Mineral Districts of England.—The present Continents once covered by the Ocean:—existing Proofs of this on many of the highest Mountains in England, Spain, South America, and various Parts of the World.—Fossil Remains of Marine Animals, Vegetables, and Quadrupeds.—Strata in which they are imbedded, formed in Succession at different Periods.—Human Skeleton in a calcareous Rock at Guadaloupe.—Inferences respecting the former Condition of the Globe.

WHEN we examine the terrestrial globe, where the solid parts are uncovered and exposed to our view, we observe vast masses of rock or stone lying in apparent confusion on each other; or, should we perceive some regularity in their position and arrangement, we soon lose sight of it again by the intervention of other rocks. In this department of nature all seems vast, unshapen, and chaotic; but we may recollect that the grandest objects in the material universe seldom present to the hasty view of the superficial observer immediate proofs of order or design.

The shepherd who first discovered that the planets were not fixed in the heavens, and saw their apparently intricate wanderings among the stars, could not possibly anticipate the regularity and harmonious simplicity of their movements, which subsequent observations have demonstrated.

Let us then endeavour to ascertain by what means we may become acquainted with the structure of the covering of our globe. Were these means bounded by the power of man to penetrate below the surface, our knowledge must ever remain very limited and imperfect; but natural operations have greatly facilitated our inquiries, and have broken the rocky pavement of the globe, and raised from vast depths the mineral substances of which it is composed. By an accurate and attentive examination of the situations where the rocks and strata are thus exposed to our research, we lay the foundation of the science denominated Geology. The first part of this science comprises the structure, composition, and arrangement of the mountains, rocks, and strata that environ our planet. The second part, the intersections and dislocations formed by metallic veins and mineral dykes*, and the direction, structure, and contents of these mineral repositories. The third part, the changes which are taking place on the surface of the globe by the agency of inundations, earthquakes, and volcanoes. There is a fourth part, which may be styled speculative geology, or an investigation of the causes that have probably operated in the formation of rocks and mountains, and also those by which the revolutions of the earth's surface have been subsequently effected. Nor is this part, as some assert, entirely useless; the advocates of particular systems have engaged in an active examination of nature to support their opinions, and have "compassed sea and land to gain proselytes:" thus numerous facts have been discovered, with which we should not have been acquainted had they remained idle in their studies. It may, however, be doubted, whether they have not sometimes been insensibly induced to close their eyes on other facts that opposed their favourite theories.

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* Dyke in the provincial language of North Britain signifies a wall. The substances which fill veins and perpendicular intersections in rocks are generally harder than the rock itself, and remain when the latter is partly decomposed, rising above the surface like a wall, and extending sometimes many miles. Instances of these are frequent in the western parts of Durham and Northumberland, and in many parts of Scotland.

The earth is now well known to be one of those globular bodies called planets, that revolve round the sun in orbits nearly circular, and in stated periods of time which bear a certain ratio to their respective distances from it. They turn round their axes with different degrees of velocity, and this motion appears to have had considerable influence on their external shape by enlarging their equatorial diameters.

In the planet Jupiter, the velocity of the equatorial parts is more than four hundred miles per minute, whilst in the same time the equatorial parts of the earth have moved only seventeen miles. A difference between the polar and equatorial diameter of Jupiter is perceptible with a telescope that has a distinct magnifying power of a hundred times, and it is ascertained to be as 12 to 13. The equatorial diameter of the earth exceeds its polar thirty-seven miles, or is only as 230 to 229.

The relative density of the sun, the earth, and of the other planets, is estimated by the attractive force which they exert on each other as they move round their common centre of gravity. The absolute density or the quantity of matter contained in the earth, compared with an equal bulk of any known substance, may be nearly determined by the attractive force which any given mass of matter exerts upon a plummet (when suspended in its vicinity) to draw it from a vertical line. This will be proportional to the absolute quantity of matter in that mass compared with that of the earth. By this method, it has been found that the mean density of the earth is about five times greater than that of water, or nearly twice the average density of the rocks and stones on the surface.

Hence it may be inferred that the interior part of the earth is solid; or, if it be cavernous, the solid matter must possess great density. It is not improbable that iron nearly in a metallic state may be one of the constituent parts of the central mass, and to this it may owe its magnetic polarity.

Dr. Halley has written a very ingenious paper (in the Philosophical Transactions) to prove that the earth is a hollow sphere, in which there is inclosed a central magnetic globe, and by the motions of this globe the variations of the magnetic needle are produced. It is evident that we have no means of verifying or invalidating hypotheses respecting the nature of the central parts of the globe. The matter thrown up from vast and unknown depths by subterranean fires is similar to that of many rocks on the surface; but we know not what changes it has undergone, or what substances were separated from it by fusion.

The rocks and mountains composing the solid parts of the earth's surface have been divided into different classes by geologists.

The names given to these classes are not free from the objection of being founded on hypothetical principles adopted before observations had been sufficiently extended to lay the basis of a solid system of arrangement.

These names having, however, been introduced into all modern books relating to geology, and also into the works of many modern travellers, it may be proper to retain them in an introductory treatise, using them in a restricted sense, without any reference to theory. The classes are denominated primary or primitive rocks; transition or lower secondary rocks; secondary stratified rocks, called by the Germans Flœtz rocks; volcanic rocks, and alluvial ground. In the present work basaltic rocks are also arranged in a separate class.

Primary rocks have been so called because no organic remains have been found in them: hence it is supposed they were formed prior to the creation of animals or vegetables. They are extremely hard, and the substances of which they are composed are crystallized. They form the lowest part of the earth's surface with which we are acquainted; and they not only constitute the foundation on which the other rocks rest, but in many situations they pierce through the incumbent rocks and strata, and form also the highest mountains in alpine districts. We are not to conclude, when we see a mountain or range of mountains bounded by a plain, that the rocks and strata of which these mountains are formed terminate at their apparent bases; on the contrary, they extend under the surface at angles more or less inclined, stretching below the lower grounds and hills, and often rising again in remote districts.

That primary rocks environ the whole globe will not admit of direct proof; but, from their frequent occurrence in mountainous districts in the most distant parts of the world that have been examined, we may infer that some of the rocks of this class constitute the foundation rock of every country. We have no means of ascertaining that the similar rocks of distant districts were formed at the same time, nor can we be certain that the rocks called primary have not once contained organic remains that were destroyed during the process by which they acquired their present crystalline structure. We may, however, with apparent probability, infer that their formation was prior to the existence of animals or vegetables on our planet in its present state, because the rocks which immediately cover them contain almost exclusively the organic remains of zoophytes, or those animals which are considered as forming the first link in the chain of animated beings.

The lowest of the secondary rocks have on this account been called by the German geologists *transition* rocks, from the supposition that they were formed when the world was passing from an uninhabitable to a habitable state. These rocks are less perfectly crystalline than the former class. They separate the primary from the upper secondary rocks, and retain some of the characters belonging to both.

The primary and lower secondary or transition rocks in Europe contain few saline or inflammable fossils*; but they are the repositories of metallic ores which are not often found in the upper secondary stratified rocks, in many of which numerous remains of vegetables and animals occur. This class contains sandstone, coal, stratified limestone, chalk, &c. Water-worn fragments of primary and transition rocks are commonly found in many of the secondary rocks: hence it is inferred that they have been formed at a later period, and hence this class receives its name.

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* In South America, according to the observations of Humboldt, both sulphur and bitumen exist in considerable quantities in rocks which have always been classed with primary.

Volcanic products are the substances ejected from volcanoes, or formed by the agency of subterranean fires. They constitute no inconsiderable portion of the earth's surface, though they are scarcely noticed by some geologists.

Basaltic rocks are by some geologists classed with those of volcanic origin: like them, they occasionally cover rocks of the preceding classes, and frequently have a regular columnar structure. But as the igneous origin of these rocks in some situations may be doubted, I have arranged them separately.

Alluvial ground consists of beds of clay, sand, and gravel, formed from the decomposed ruins of other rocks, and carried by water into valleys and plains, or over the lower declivities of hills and mountains.

These classes have their appropriate mineral productions; and it would be as vain to seek for common coal in the primary and transition rocks, as to expect statuary marble or metallic veins in the upper secondary strata or in alluvial ground.

The situation of the various mineral productions of England offers a proof of this. From the western side of the county of Dorset a waving line may be traced in a north-east direction to near Scarborough in Yorkshire: see the map A. A. The whole of the country between this line and the German ocean is composed of chalk, calcareous sandstone, and other secondary strata, or alluvial ground, in which no beds of workable coal or metallic veins occur: it is coloured yellow in the map. The same strata appear again on the eastern side of Durham and Northumberland, but are separated from those of Yorkshire by the alum rock near Whitby, and the Cleveland hills marked B. This part of England I denominate the low district. On the coast of Lincolnshire and part of Yorkshire there is a subterranean forest about seventeen feet under the present high-water mark. This forest appears to have extended eastward, as stumps and roots of trees may be seen at low water at a considerable distance from the coast: it is coloured green. West of the line A. A. the country is composed of secondary strata of a different kind, in many parts of which are beds of ironstone and coal: it is coloured blue. This I denominate the middle district. It is bounded on the north by mountains of metalliferous limestone, which range along the line C. C. and terminate in Derbyshire. In the west this district extends to the mountains of Wales and Devonshire. See the map. The principal coal fields are situated in that part of the middle district which extends from Derbyshire to Northumberland and that part of Wales bordering the Bristol channel. See chapters fourth and ninth. On the western side of Cumberland the coal strata border a small part of the alpine district, and dip under the sea. The strata on the eastern side of the island generally dip or decline to the south-east. On the west of the line marked C. C. they are more broken, and dip in various directions. The line C. C. is continued from Derbyshire through the southern counties, to denote that no valuable metallic veins are found east of it in any part of

England.——Along the western side of the island the primary and transition mountains are situated, in which metallic ores occur. They constitute the alpine parts of England, extending from Cornwall and Devonshire, through Wales, into the north-west parts of Yorkshire and Lancashire, and through Westmoreland and Cumberland, and from thence to the northern part of Scotland: they are coloured red. In the direction E. E. all the rock salt and most of the brine springs are situated: other particulars in the geology of England will be subsequently adverted to. The writer is not aware that this arrangement has been before noticed: it is introduced here, to excite the attention of persons entering on the study of geology, who may be more impressed by local illustrations than by general descriptions.

Three-fifths of the surface of the globe are covered by the sea, the average depth of which has been estimated at from five to ten miles: but great changes have taken place in the relative level of the present continents and the ocean, which, in former ages, rolled its waves over the summits of the highest mountains. Of this, demonstrative proofs exist in our own island and in various parts of the world.

The calcareous or limestone mountains in Derbyshire, and Craven in Yorkshire, rise to the height of about two thousand feet above the present level of the sea. They contain through their whole extent fossil remains of zoophytes, shellfish, and marine animals, but more abundantly in some parts than in others. Particular species occupy almost exclusively distinct beds, and in some situations the whole mass appears a compact congeries of these marine organic remains. In Derbyshire the beds of limestone are separated by different beds of a stone called toadstone, varying in thickness from fifty to one hundred and fifty feet, in which are no organic remains; but we meet with them again whenever we come to the limestone either above or below the toadstone.

The distinct characters which the organic relics found in the separate beds in these mountains present, prove that they have not been brought there by any sudden inundation. They must have remained for ages under the ocean prior to their elevation above its surface.

The mountains of the Pyrennees are covered in the highest part at Mont Perdu with calcareous rocks containing impressions of marine animals; and even where the impressions are not visible in the limestone, it yields a fetid cadaverous odour when dissolved in acids, owing, in all probability, to the animal matter it contains. Mont Perdu rises ten thousand five hundred feet above the level of the sea; it is the highest situation in which any marine remains have been found in Europe*. In the Andes they have been observed by Humboldt at the height of fourteen thousand feet.

In England, the calcareous mountains I

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* By a recent admeasurement, it appears that the altitude of Mont Perdu is considerably less than is here stated; but the accuracy of this admeasurement may be doubted, as these mountains are distinctly visible at the distance of one hundred and twenty miles.—Cette montagne est non-seulement la plus haute des Pyrennées, elle est encore la plus élevée de nôtre hémisphère, où l'on trouve des débris organidiques: elle est de tous les monumens connus des derniers travaux de la mer la plus considérable par son volume, et la plus remarquable par sa structure; un pareil terrein est classique pour l'étude des montagnes secondaires, et pour l'histoire des dernières révolutions du globe.—*M. Raymond.*

have described contain no remains of vegetables; but in the thick beds of shale and sandstone lying upon them are found various vegetable impressions, and above these regular beds of coal, and sometimes strata containing shells of muscles. In the earthy limestone of the upper strata are found fossil flat fish, with impressions of the scales and bones quite distinct; in these strata we also meet with fossil remains of the alligator, and with numerous zoophytes, different from those in the lower rocks; and lastly, in the beds of clay covering chalk, the bones of the rhinoceros, the elephant, and the mammoth, are not uncommonly discovered. The sagacious naturalist Cuvier has examined these bones from different parts of the world with much attention, and has observed characteristic variations of structure, which prove that the greater part belong to animals not now existing on our globe: nor have many of the various zoophytes and shell fish, found in calcareous rocks, been discovered in our present seas.

The fossil remains of animals not now in existence, entombed and preserved in solid rocks, present us with durable monuments of the great changes which our planet has undergone in former ages. We are carried back to a period when the waters of the ocean have covered the summits of our highest mountains, and are irresistibly compelled to admit one of two conclusions, either that the sea has retired and sunk far below its former level, or some power operating from beneath has lifted up the islands and continents, with their hills and mountains, from the watery abyss to their present elevation above its surface.

These organic remains present also undeniable proofs of another fact equally interesting. Every regular stratum in which they are disseminated, was once the uppermost rock, however deep it may be below the present surface, or with whatever rocks it may now be covered. This inference is not the less conclusive, whether we suppose that the animals lived and died where their remains occur, or whether they were aggregated and carried by marine currents into their present situation. Hence we learn that the secondary strata were formed in succession over each other, and thus these fossil remains preserve the records of the ancient condition of our planet, and the natural history of its earliest inhabitants*. The unknown causes by which zoophytes, fish, vegetables, and quadrupeds were buried in separate strata, operated at distant intervals of time; for these different organic remains are not found intermixed together, except in alluvial soil near the surface, or in stony masses formed from the fragments or debris of various rocks which have been broken down, and subsequently consolidated, as in the fissures of the calcareous rock at Gibraltar. If the bones of man, or of quadrupeds resembling existing species, have casually been found with fossil remains peculiar to the lower or more ancient strata, I believe a careful examination of all the circumstances would generally explain the apparent anomaly. I shall state some remarkable facts of this kind.

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* An opinion has lately been advanced by Professor Jamieson, in the Memoirs of the Wernerian Society, vol. ii. that many of the secondary strata are of cotemporaneous formation; but the existence of organic remains is a demonstrative proof that the strata in which they occur were formed in succession over each other; for it will not surely be maintained that the marine animals in a lower stratum were coexistent with those found in the rocks which cover them, which are generally of a different species or genus.

In sinking for lead in a mountain near Wirksworth, in Derbyshire, in 1663, a cavern was unexpectedly discovered, in which was found the entire skeleton of an elephant; its skull was so large, that it is stated to have held four bushels of corn. One of the teeth I have seen in the possession of Mr. Watson, of Bakewell. There can be little doubt that this cavern had once been open, and was afterwards closed by the deposition of calcareous earth forming stalactites, instances of which are common in Derbyshire. Into this cave I conceive the animal had retired to die, at a period long after the existence of the marine animals which are imbedded in the surrounding rock.

The other instance, apparently more surprising, lately came to my knowledge when engaged in a mineralogical examination for the Earl of Moira, in the vicinity of Ashby de la Zouch, in Leicestershire: it will evince how cautious we ought to be in drawing general conclusions in geology from single facts. A thick bed of coal belonging to his lordship, at a place called Ashby Wolds, is worked at

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the depth of two hundred and twenty-five yards; it is covered with various strata of ironstone, coal, and solid rock. On an estate adjoining to his lordship's manor, in the same bed of coal, (which is ninety-seven yards below the surface,) the entire skeleton of a man was found imbedded. No appearance existed of any former sinking for coal; but the proprietor ordered passages to be cut in different directions, until the indication of a former pit was discovered, though the coal had not been worked. Into this pit the body must have fallen, and been pressed and consolidated in the loose coal by an incumbent column of water, previously to the falling in of the sides of the pit.

The imperfect skeleton of a woman, imbedded in a kind of calcareous sandstone, recently brought from Guadaloupe, and exhibited in the British Museum, may appear to invalidate what was asserted in the first edition of this work, that no instances have been known of human bones being found in regular stratified rocks, nor even in undisturbed alluvial ground, where the remains of extinct species of quadrupeds are not unfrequently met with. Due attention to all the circumstances will reconcile that assertion with the present fact. The skeleton from Guadaloupe is described as having been found on the shore below the high-water mark, among calcareous rocks formed of madrepores, and not far from the volcano called the Souffriere. The bones are not petrified, but preserve the usual constituents of fresh bone, and were rather soft when first exposed to the air. Specimens of the stone which I have in my possession, that were chipped from the same block, present, when examined with a lens, the appearance of smooth grains aggregated and united without any visible cement. Now it is well known that on the shores of Sicily, and other parts of the world, heaps of loose sand become consolidated in a few years*. It cannot therefore excite surprise, that in a volcanic island like Guadaloupe, subject to violent convulsions from earthquakes and impetuous hurricanes, human bodies should occasionally be discovered, that have been enveloped in driving sands, which have subsequently become indurated. The situation of this skeleton near the sea shore, the state of the bones, and the nature of the stone in which they are imbedded, take away the probability of their high antiquity.

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* According to Saussure, the loose sands in the Gulf of Messina became so firmly consolidated in three or four years, as to serve for millstones. This he attributes to a calcareous infiltration; but it may be doubted whether this infiltrated liquor does not contain silex, as silex is known to exist in the warm springs of volcanic districts.

The absence of human reliquiæ in stratified rocks, or in undisturbed alluvial ground, would appear to indicate that man is the most recent tenant of the globe, and is coincident with the oldest records or traditions of the human race. Those who are desirous of pursuing such inquiries may consult Parkinson's Organic Remains, and the elaborate researches of Cuvier. Sufficient has been advanced to prove that great revolutions have changed the antient condition of the globe; and the changes now taking place in distant parts of the world, by the agency of subterranean fires, are too important and extensive to admit us to believe that our planet is an inert mass, agitated at intervals by the blind fury of tumultuous elements. The same wisdom which regulates the external universe has also "laid the foundations of the innermost parts of the earth," and appointed determinate laws, by which its surface is renovated, and adapted to the support of vegetable and animal life.

CHAP-

CHAPTER II.

ON THE STRUCTURE AND COMPOSITION OF ROCKS.

Terms employed in Geology.—Rocks, Simple or Compound: Varieties of their internal Structure.—External Structure of Mountain-Masses:—Indeterminate, Stratified, Columnar, Tabular, and Globular:—the three latter the Effects of Crystallization en Masse.—Tabular Structure erroneously confounded with the Stratified.—Elementary Substances.—Minerals of which Simple and Compound Rocks are principally formed.

No inanimate objects on the terrestrial globe excite in the mind such sublime emotions, as the immediate presence of lofty and precipitous mountains that rear their heads in awful silence amidst the clouds, and secure in their immensity remain unchanged, while successive generations and empires pass away from the earth.

"Surely there is a hidden power that reigns
'Mid the lone majesty of untamed nature
Controlling sober reason———"

To the geologist such scenes are peculiarly interesting; for it is here he must receive his most instructive lessons, and learn the antient and present condition of the globe.

It may be advanced as an additional recommendation to the study of geology, that it leads its votaries to explore alpine districts, where the surrounding scenery and the salubrity of the air conspire to invigorate the health, and give to the mind a certain degree of elasticity and freshness, which will enable them on their return to discharge with greater alacrity the duties of active and social life.

However delightful or inviting any new science may be, the knowledge of it must be preceded by the irksome labour of learning its terms,—for every science has a language peculiar to itself. It were much to be desired that this technical language should not deviate more than is absolutely necessary from that of common life; and such will be the case whenever plain sense shall be more valued than pedantic affectation.

The first persons who directed the attention of men of science to the mineral kingdom were Germans, and the names they introduced from the working miners of their own country, though unmeaning and barbarous, have been received without examination: it is, however, so desirable that each substance or mode should have only one name, that it is generally better to retain terms in common use, than to substitute a different nomenclature; but the progress of science sometimes renders indispensable the introduction of new words, and the rejection of old ones—"Dies diem docet." I offer these remarks as an apology to the general reader, for any quaintness which he may perceive in the terms employed in describing the characters of rocks and minerals; it is my intention to render the technical language as simple as is consistent with requisite precision.

The external character and physical qualities of the minerals which compose rocks claim the first attention of the geologist. A mineral or an entire rock is denominated SIMPLE, which presents to the sight one unmixed homogeneous substance, whatever be the constituent elementary parts of which it may be composed. Such are limestone, roofslate, and serpentine. COMPOUND rocks are composed of different mineral substances, which are either *cemented* by another mineral substance that serves to unite them, as in sandstone and puddingstones, or crystallized and united without a cement, as in granite.

Fragments of stone broken from *simple rocks* display the structure of the internal parts*. This internal structure may be denominated the stony structure, and is either

Compact, without any distinguishable parts or divisions—or

Earthy, comprised of minute parts resembling dried earth.

Granular, composed of grains.

Fibrous, composed of long and minute fibres.

Radiated, when the fibres are broader and flattish, and so large as to be distinctly visible.

Lamellar or *Foliated*, composed of minute plates laid over each other in different directions.

Porous, penetrated by pores.

Cellular or *Vesicular*, when the pores swell into rounded cavities like bladders, as in some lavas.

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* The face of the broken part is called the fracture, the conchoidal fracture consists of concavities and convexities like the impression of shells.

Slaty or *Laminar*, composed of straight parallel thin plates, or laminæ.

The structure of *compound rocks* may also be *Slaty*,—or

Granitic, composed of grains or crystals closely united without a cement.

Porphyritic, consisting of a compact ground in which distinct crystals are imbedded, or of a granitic ground in which some of the crystals are much larger than the rest.

Amygdaloidal, (from the Latin *amygdala* an almond, on account of the kernel-shaped cavities,) when composed of a compact ground with cavities which have been filled up with another mineral substance.

Conglomerated, composed of fragments or rounded stones cemented together, as in breccias and puddingstone.

The external structure of rocks *en masse*, or considered as mountain masses, is as distinct from their internal structure as the shape of a building from that of the bricks or stones of which it is composed, though this distinction has been generally overlooked. The external structure of rocks, as forming mountain masses, may be

Stratified, or stratiform.

Tabular, or in large plates.

Columnar, or polygonal.

Globular, or in spherical masses.

In*determinate*, which includes all unstratified rocks that have no determinate shape.

Stratified mountains or rocks are those which are composed of layers of stone, laid over each other, and divided by parallel seams like the leaves of a closed book. In these seams or partings, which divide the strata, there are frequently thin laminæ of soft earthy matter; but sometimes the surfaces of the upper and lower stratum are so closely joined, that it requires a considerable force to separate them. These layers are denominated strata; they extend through the whole mountain or mass, their length and breadth being much greater than their thickness. If the thickness of any stratum exceed two or three yards, it is more usually denominated a bed; and if it lie between beds of stone of a different kind, it is said to be imbedded. Strata always decline or dip down to some point of the horizon, and of course rise towards the opposite point. A line drawn through these points is called the line of their dip; another line drawn at right angles to this, marks the course along which the strata stretch out to the greatest extent; —it is called the line of bearing. If a book be raised in an inclined position, with the back resting lengthways upon the table, the leaves may be supposed to represent different strata; then the direction of the leaves from the upper edges to the table will be the line of dip, and their direction lengthways the line of bearing; and the angle they make with the table will be the angle of inclination. Strata are, however, sometimes waved or bent in both their directions, and are frequently broken; which makes it more difficult to ascertain their true position.

It is generally supposed that stratified rocks were formed by the motion of water, which arranged them in succession over each other in the same manner as the muddy waves of the ocean deposit their contents in regular layers upon the shore. This mode of formation is called mechanical deposition. It has also been erroneously though generally believed, that all rocks divided by parallel seams into separate layers, were formed mechanically by the same means. Thus, slate has been represented as "most distinctly stratified," because it divides into layers or plates; but this division is the effect of its chemical composition, and generally owing to the magnesian earth, or to the mica, which it contains. It is the result of crystallization, or the internal arrangement of the particles, as evidently as the laminæ in a crystal of felspar, or in a plate of mica; and with equal propriety might we say that a plate of a crystal was stratified as a plate of slate. The division of the laminæ of slate is frequently in a different direction from that of the thick plates which have been called strata, a decisive proof that the slaty structure is not owing to stratification. The structure which is caused by chemical agency, or by crystallization, ought not to be confounded with mechanical depositions. I believe a proper attention to this difference would remove many difficulties from geology.

The tabular structure consists of tables or plates of rock, separated by seams which have generally a vertical direction. This has been confounded with stratification, and has given rise to much confusion and contradiction in the descriptions of rocks and mountains;

tains; some geologists asserting, and others denying, the stratification of the same rock. The laws of crystallization have but recently attracted the attention of philosophers, and their researches have been hitherto confined to effects on a small scale. The crystallization of mountain masses, however, is equally deserving notice, as to this is owing the columnar, the tabular, and the globular structure of rocks: but, like the crystallization of smaller substances, this structure is more or less regular, and they pass by every gradation from the most perfect symmetrical arrangement to an indeterminate shapeless mass.

The columnar structure is peculiar to certain rocks, which are divided into polyhedral prisms, or large crystals, that are frequently laid regularly on each other, and form vast ranges of natural columns, as at Staffa, the Giant's Causeway, in Iceland, and in many volcanic countries.

The globular structure consists of balls of different sizes, sometimes detached, at other times imbedded in rocks of the same kind. These balls are frequently composed of concentric spherical layers.

However numerous the varieties of stones or rocks may be, the elementary substances of which they are composed are very few. They consist principally of the four earths, silex, clay, lime, magnesia, and of the oxyd of iron. The other solid substances most abundant in the mineral kingdom are carbon and sulphur. From the five first-mentioned substances, more than nineteen parts in twenty of the external parts of our planet are composed.

Of these, *silex*, or the earth of flints, is the most abundant, particularly in the primary mountains. It derives its name from the Latin word for flint, which is almost entirely composed of this earth: it also exists nearly pure in rock crystal, and the mineral called quartz. Stones or rocks of which silex forms the predominant part are extremely hard, and strike fire with steel: such rocks are denominated siliceous.

Clay, or *Alumine*,—Latin, *argilla*,—Fr. *argille*,—is a substance which in a mixed state is well known; but pure unmixed clay is one of the rarest substances in the mineral kingdom. This earth is soft, smooth, and unctuous to the touch; it strongly absorbs water. Where it exists in stones in the proportion of thirty per cent. it communicates in some degree these properties: such rocks are called argillaceous; they generally contain a notable portion of iron, which appears to have a greater affinity for this earth than for any other*.

Lime,—Lat. *calx*,—Fr. *chaux*,—is a well-known earth combined with carbonic acid, in which state it forms limestone, marble, and chalk: these only differ from each other by different degrees of hardness, or of crystallization. Mountains composed of lime are denominated calcareous. When lime is united with sulphuric acid, it forms the stone called gypsum, which is softer than limestone, and does not, like it, effervesce with acids. Calcareous earth mixed with common clay forms marle.

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* Though clay communicates a soft quality to most stones of which it forms a principal constituent part, a very remarkable exception to this is offered in adamantine spar and the sapphire, which nearly equal the diamond in hardness. Klaproth, one of the most laborious and eminent chemists of the present age, has analysed these stones: the former contains 90 parts in the 100 of pure clay; the latter 95 parts in the same quantity. "What a high degree of cohesive power (he observes) must nature command, to be able to transform such a common substance as clay (aluminous earth) into a body so eminently distinguished and ennobled as the sapphire by its hardness, brilliancy, and its resistance to the action of fire, of acids, or the effects of all-destroying time!"—*Klaproth's Essays*.

Magnesia has rarely been found pure in a native state. It enters into the composition of some rocks, to which it generally communicates a soapy feel, a striated or striped texture, and sometimes a greenish colour.

Iron appears to be more abundant than magnesian earth; it forms a constituent part of numerous rocks and stones; to it they most frequently owe their colour; the earths when pure are white. Iron when in combination with the earths is like them an oxyd, or a metal united with oxygen. To the presence of iron, the increase of specific gravity in all stones or earthy minerals may be attributed, if it much exceed 2, 5, or approach 3: in other words, if they are nearly three times heavier than an equal bulk of water. Gems and the earths barytes and strontian are exceptions, but these never form entire rocks. The presence of iron not only increases the weight, and darkens the colour of numerous rocks and stones, but is one principal means of their decomposition. For iron exists in stones in two states of oxygenation, as the black or the red oxyd. When the former is exposed to air and moisture, it absorbs a greater portion of oxygen, and is converted into a brown ochery incrustation, which peels off, and exposes a fresh surface of the stone to a similar process. A minute portion of oxyd of the metal called *manganese* is also found in some rocks and stones.

The abovementioned substances*, either separately or combined, form all the simple minerals, constituting compound rocks; and as these are of frequent occurrence in geology, a brief description of the most important may be of use to those who are entering on the study. These are quartz, felspar, mica, talc, chlorite, hornblende, serpentine.

Quartz occurs in masses, in grains, in rolled pieces or pebbles, and in crystals. It is one of the hardest minerals of which mountain masses are composed; it gives plentiful sparks with steel; it breaks with a smart stroke of the hammer; the surface of the fracture in crystallized quartz is conchoidal, in uncrystallized, splintery;—the lustre is vitreous. Crystals of quartz, or rock crystals, as they are commonly denominated, have different degrees of transparency; the blue varieties are amethysts. The most common forms of the crystals are six-sided prisms terminated by six-sided pyramids, or two six-sided pyramids united, forming a dodecahedron whose faces are isosceles triangles. Uncrystallized quartz is seldom transparent, most frequently translucent, but sometimes opaque. Its colours are various shades of white, gray, brown, yellow, red, and green. It yields a phosphorescent light and peculiar odour when rubbed. Quartz is composed of siliceous earth combined with a very small portion of alumine. It is infusible when unmixed; but with alkalies it melts easily, and forms the well known substance called glass. It is not acted upon by any acid except the fluoric. Quartz exists in veins intersecting mountains, and it sometimes forms large beds, and even entire mountains, which are composed of this mineral in grains united without a cement, called granular quartz. Fragments or crystals of quartz are common in compound rocks. Grains of quartz form a principal constituent part of most sandstones. The milk white pebbles in gravel are composed of quartz. Flint, chert or hornstone, opal, chalcedony, and agate, are different modifications of siliceous earth, which in their chemical composition differ little from quartz. Combined with a large portion of alumine and iron, quartz loses its translucency and passes into jasper, which forms beds in primitive mountains, and is said to compose the substance of entire ranges of mountains in Asia.

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* These substances may probably be reduced to still simpler elements, as it is now ascertained that the earths are metals united with oxygen; and it is also probable that the metals have all one common base. We shall, however, still consider those substances as simple, which are not known to exist in nature in a decompounded state.

Felspar or *feld-spar* (a name received from the Germans) is a constituent part of numerous rocks. It is hard in a somewhat less degree than quartz, and is more easily broken. It is laminar, or composed of thin laminæ or plates, by which it may be generally distinguished from quartz. The crystals are most commonly four-sided or six-sided prisms, whose length is greater than the breadth. It has a shining lustre. The colours are white, gray, milk white, yellowish, or reddish white, sometimes inclining to green. The red passes through various shades, from a pale to a deep red. Crystallized felspar is translucent*. It may be melted without the admixture of alkalies, and forms a glass more or less transparent, which quality it derives from the lime or alkali that compose part of its constituent ingredients; but different specimens of this mineral vary, according to the analyses of the same chemist.

Silex	63	—	74
Alumine	17	—	14
Potash	13	—	
Lime	3	—	6
Oxyd of iron	1	—	
Loss	3	—	6

Others give the proportion of silex 46, alumine 24, lime 6.

The existence of potash or the vegetable alkali in felspar, is a fact deserving particular attention: it may be owing to this circumstance that felspar is so frequently observed in a soft or decomposing state, although its hardness is little inferior to that of quartz when undecayed. Those felspars which are durable are probably free from potash. Felspar is sometimes uncrystallized and compact, in which state it is classed by the French mineralogists with petrosilex or hornstone. Compact felspar however differs from hornstone, the latter being infusible without the addition of alkalies.

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* In the language of mineralogists, *translucent* implies merely the transmission of light, as in ground glass, through which objects cannot be seen.

Mica derives its name from the Latin *micans*, glittering. It is known as the substance called Muscovy glass, and has a splendent lustre. It consists of very thin leaves or laminæ, which may be easily separated with a knife. The plates are elastic, by which it may be distinguished from the mineral called talc. The thin plates are transparent. The colours of the thick plates are yellow, gray, blackish green, white, and brown. The surface may be scratched with a knife: it melts into an enamel with the blowpipe: it is rarely met with crystallized.

Talc nearly resembles mica in appearance. The plates are flexible, but not elastic: it is much softer than mica, and is infusible; its colours generally incline towards green: but it is sometimes a silver white: it has a soapy feel. *Chlorite*, which is nearly allied to talc, derives its name from *chloros*, the Greek word signifying green. This mineral is of a darkish dull green colour; it has a glistening lustre; its structure is minutely foliated; it is soft, and rather unctuous. The constituents of these three minerals are,

	Mica.		Talc.		Chlorite.
Silex	50	—	62	—	41
Alumine	35	—	2	—	6
Lime	1	—		—	1
Magnesia	2	—	27	—	40
Oxyd of iron	6	—	3	—	10
Water and loss	6	—	6	—	2

but these proportions vary in different specimens.

Hornblende, to which the French give the name of *amphibole*, forms a constituent part of many rocks, and appears to connect the primary with those which are of volcanic origin. It is of a black or dark green colour: it is heavier but less hard than quartz or felspar; it may be scratched with a knife, and the colour of the streak is a light green: it yields a bitter smell when breathed upon, and melts easily into a black glass. Common hornblende is often confusedly crystallized; it sometimes forms entire mountains, or beds in mountains, and is very commonly met with, in granular pieces, as an ingredient in compound rocks: when it becomes more abundantly and minutely disseminated in them, it forms what are denominated trap and basaltic rocks, whose origin has greatly divided the opinions of geologists. Hornblende and the rocks to which it is most nearly allied contain as under:

	Hornblende.	Basalt.	Obsidian or volcanic glass.	Lava.
Silex	42	44	72	49
Alumine	8	16	12	35
Magnesia	16	2		
Lime	9	9	sometimes	4
Oxyd of iron	23	20	2 with manganese.	12
Soda		4	6 with potash;	
Manganese	1			
Water and loss				

Another mineral substance called *serpentine*, from its spotted colours resembling the serpent's skin, will afterwards be described as forming entire rocks: it differs in composition from hornblende by having a larger portion of magnesia and less iron; it may perhaps be regarded as an intimate combination of hornblende and talc or chlorite. Its component parts, as given by different chemists, are as under:

Silex	45	29	45
Alumine	18	23	
Magnesia	23	34	33
Iron	3	4	14 with a trace of alumine.
Lime			6
Water and loss	11	10	8

From these analyses it is evident that the specimens vary in their component parts; in some, the proportions are almost the same as in hornblende; in others, they more nearly agree with talc and chlorite.

Perhaps many varieties of argillaceous schistus may be considered as intimate mixtures of hornblende, felspar, and mica. Hornblende rocks pass by gradation into slate.

By a slight variation in the proportion of the ingredients, or by the union of two or more of the simple minerals, limestone, quartz, felspar, mica, talc, chlorite, and hornblende, all rocks both simple and compound may be composed; and whoever has observed the gradations by which they pass into each other, will be more inclined to contract than extend their nomenclature. A few names by which they may be classed under different families, appear to be all that the present state of the science will admit; but these names must be accompanied by a precise description of the individual rock, if we mean to convey useful information. No general terms can be used that will comprise the infinite variety of combinations in the mineral kingdom; for it may be safely affirmed, that no two rocks from different districts, which have the same name, are precisely the same: even from the same mass of rock, two pieces might frequently be broken, essentially alike, though differing in their appearance, which would be classed as different substances by those who view nature only through the spectacles of artificial arrangements.

CHAPTER III.

ON THE POSITION AND ARRANGEMENT OF ROCKS AND STRATA.

Different Positions explained.—Relative Ages of Rocks determined in some Instances by their Position, and by the Substances imbedded in them. —Appearances presented by stratified parallel Rocks, illustrated by a Section of the Country from Sheffield to Castleton.—Excavation of Valleys.—Valleys formed by the Dislocation of Rocks and Strata.—Beds of Gravel: Opinions respecting their Formation.—Transportation of Blocks of Granite to distant Countries, how effected.—Bones of large Quadrupeds transported without Injury by similar Operations.—Hills and Mountains, Observations respecting their Declivities.

THE relative position of rocks, or the order in which they succeed or cover each other, and the manner in which they are laid, forms an interesting subject of geological inquiry, as it is intimately connected with the structure of the earth's surface, and is supposed to determine the relative ages of different mountain masses. The German geologists assert that the primary and secondary rocks occur in a certain determinate order, and encircle the globe in different layers like the coats of an onion. According to this system, all the principal primary and secondary rocks are what they denominate universal formations, or are formed universally over the nucleus of the earth in a regular series, which is the same in every part of the world. This assertion is not confirmed by experience to the extent which these geologists contend for.

There are, however, certain rocks that generally lie below rocks of another class, and contain no remains of organic life: it is inferred that they are the oldest rock formations with which we are acquainted, and hence they have received the name of primary.

No inference can appear more legitimate than this: "The rock which supports another must be older than that which rests upon it, if their original position has not been changed:" But this conclusion, when examined with attention, will fairly admit of doubt with respect to those rocks which are crystalline like the primary. These were formed by chemical affinity from a state of solution, or by crystallization from a state of fusion: if by the latter mode, all the different materials may have been arranged from the same mass at the same time, and the upper and lower rocks may have a cotemporaneous origin. If a mass of melted matter from a furnace cool slowly, the internal and external parts will vary both in their physical and chemical properties; but it cannot, on this account, be said that the former are older than the latter. In those rocks which have been subjected to external agency, as in sand rocks which contain fragments that have been rounded by water, their situation evidently proves that they were formed after the rocks on which they rest.

It has been before observed, that those rocks which contain different organic remains, separated by beds or strata in which no such remains occur, must have been formed in succession over each other, and probably at very distant intervals of time. This inference appears to me conclusive, nor can it be invalidated by the crystalline arrangement and cleavage of some of those rocks. For calcareous stalactites, which we know were formed by successive depositions of matter, acquire, by some process of nature, a crystalline arrangement of the particles,

ticles, and cleave into regular rhombs, like the most perfect crystals of carbonate of lime.

There are also two modes of superposition, which mark distinctly the relative ages of the different classes of rocks in which they occur: these have been denominated the '*conformable*' and the '*unconformable overlying*' positions.

The conformable position is represented pl. I. fig. 1. where *a* is the foundation rock, on which the rocks 2, 3, 4, &c. are laid, and may be supposed to encircle or to cover one side of the mountain with a general conformity to the shape of the lower rocks on which they appear to be moulded; preserving the same elevations, depressions, and undulations, as those of the foundation rock. Rocks which occur in this position, have a general but not an invariable order of succession. Granite is the foundation rock on which gneiss, micaceous schist, and slate are laid; next succeed transition rocks, and over these the secondary stratified rocks.

The position which the Germans call unconformable and overlying, is represented plate I. fig. 2. where *d* is a mass of superincumbent

Pl. 1.

Fig. 1. Conformable position of Rocks.

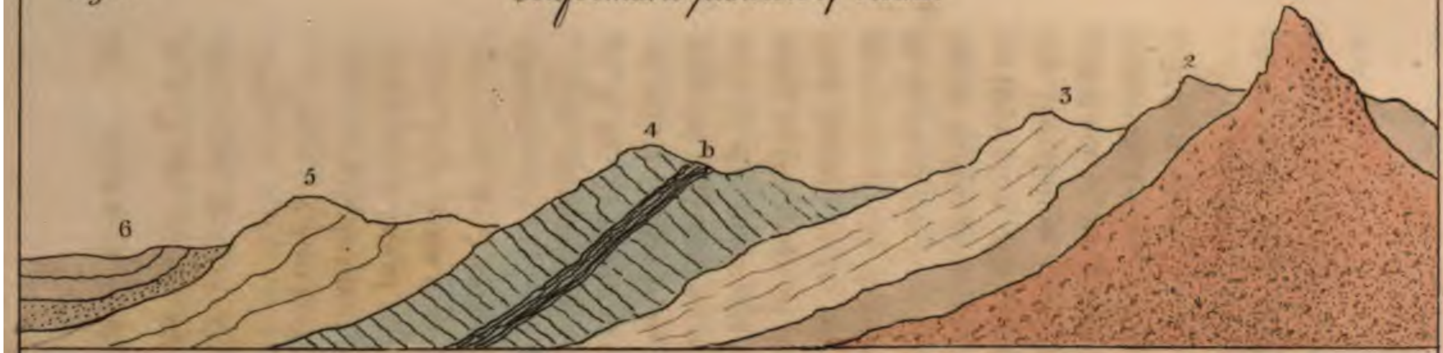
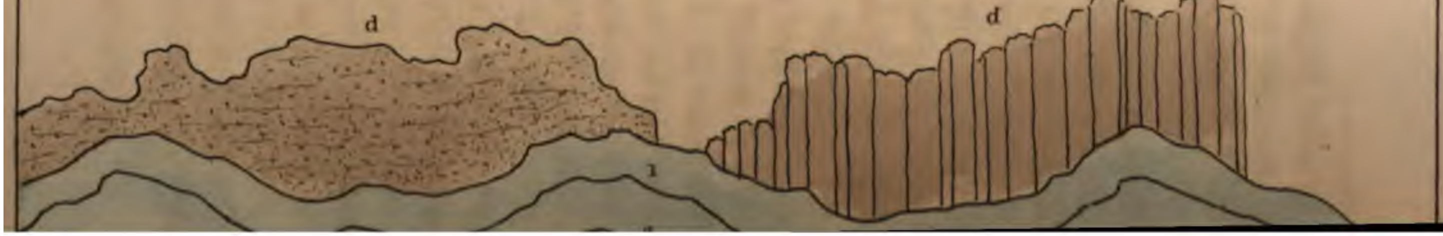


Fig. 2. Superincumbent Rocks.



cumbent rock resting upon the rocks 1, 2, 3, without any conformity to the shape of the lower. Whatever theory we adopt respecting the formation of rocks, we must admit that the superincumbent rocks in this situation are of more recent origin than those which they cover: the lower must have been hard and unyielding when the upper were thrown upon them. If a thick stream of lava, as frequently happens, were to flow over a range of conformable rocks, filling up the cavities and inequalities of the surface,—when it became hard by cooling, it would form a bed of superincumbent unconformable rock. Such instances are common in volcanic countries. Very extensive ranges of rocks and mountains occur in this position in various parts of the world, not only covering the primary but the secondary rocks. These will hereafter be described under the name of porphyry, sienite, and basalt; they frequently assume the columnar structure, and sometimes form vast ranges of natural pillars, as at Staffa one of the Hebrides, on the north of Ireland, in Iceland, Sicily, and many volcanic countries.

It is deserving of notice, that many of the rocks to which this position is peculiar have a near resemblance both in their composition and structure to volcanic products.

The compound term 'unconformable and overlying,' introduced from the Germans, is extremely harsh, and may be omitted, as the simple term 'superincumbent,' when applied to basaltic rocks and those of porphyry and sienite, to which this position is almost peculiar, will generally be sufficient to distinguish it from that of conformable and imbedded rocks.

The position of imbedded rocks is represented plate I. fig. 1. where *b* is supposed to be a section of a bed of limestone lying between two rocks of slate. The slate in this instance is the principal, and the limestone the subordinate rock.

Stratified secondary rocks are generally conformable or parallel to each other, for a certain extent; and this conformity may sometimes be traced over a whole district, the different strata having the same undulations, and rising and falling together until they are broken by rents, which have elevated them on one side, and depressed them on the other.—Their continuity is sometimes interrupted by the excavation of valleys formed

by

Fig. 1. Arrangement of the Strata from Sheffield to Castleton.

Fig. 1.

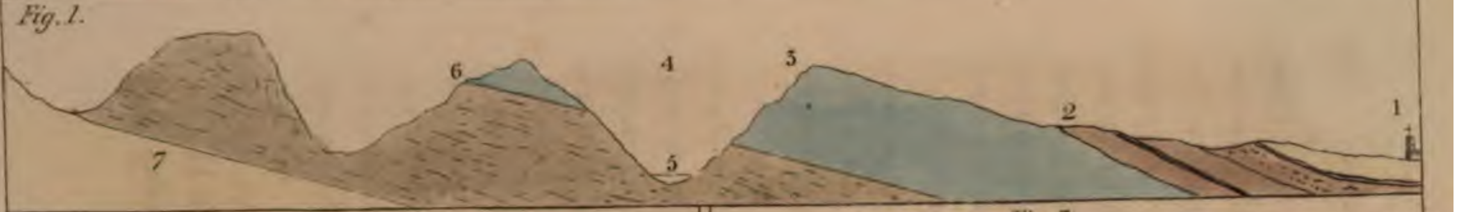


Fig. 2.

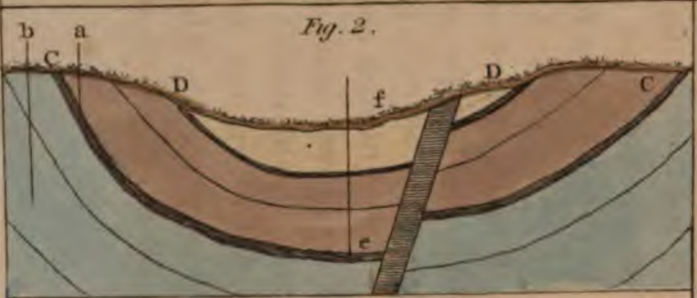


Fig. 3.

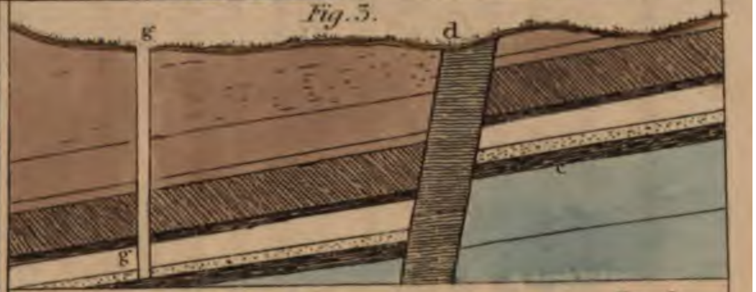


Fig. 4.

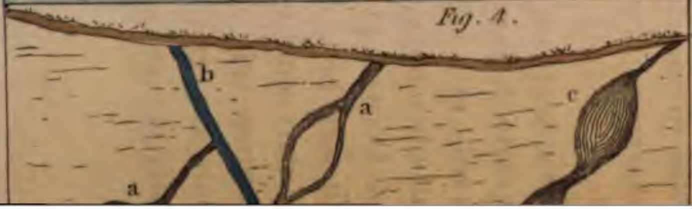
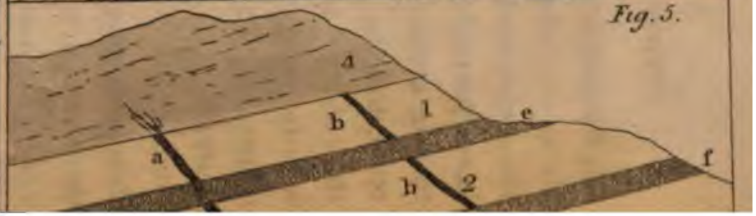


Fig. 5.



by the rivers which flow through them.—In these instances we shall frequently observe the same rocks, or strata, which form the lower part of the hills on one side of the vale, resting upon the summits of the hills on the opposite side; which is owing to the general rise of the strata in that direction.—This will be more distinctly understood by consulting plate II. fig. 1. which is intended to represent the general rise of the strata from Sheffield in Yorkshire to Castleton in Derbyshire, intersected by the valley through which the river Derwent flows.

The town of Sheffield, fig. 1. is built over coal strata, which rise towards the west, and disappear in that direction about five miles from Sheffield (2). Here the under rock makes its appearance (3), which is a bed of coarse gritstone, more than one hundred and twenty yards in thickness, forming the summits of all the mountains as you advance to the vale of Derwent (4). The grit-rock rests upon a thicker bed, of a different kind, composed of slaty sandstone, represented (5). On the western side of the valley, this rock exists only as a cap or covering on Whin-Hill, a lofty mountain, marked (6). Two miles further west the grit-rock disappears, and the slaty sandstone which is the base of Whin-Hill forms the summit of the celebrated Mam Tor, or the shivering mountain. The compact limestone (7) here makes its appearance as the base of Mam Tor, and further west the same limestone forms entire mountains. The difference observable in the rocks east and west of the Derwent is owing to the general rise of the strata in the latter direction.

In other instances, the difference in the position of rocks on the opposite sides of a valley is occasioned by the elevation or depression of one of the sides; for sometimes the continuity of rocks and strata is so entirely broken by the great convulsions which have agitated the surface of the globe, that a whole series of strata disappear, and a fresh series of different rocks supply their places.

Deep valleys have also been formed by a sudden sinking down of the surface, occasioned by earthquakes and other subterranean agents. The chasms thus made have been widened by mountain torrents and inundations, which have covered the bottom with loose rocks and stones borne down in their descent.

Small water-worn pieces of stone and round pebbles, intermixed with sand and clay, constitute gravel, which frequently covers the surface to a considerable depth in detached masses called gravel beds: these are sometimes very extensive, and conceal the nature and arrangement of the lower rocks or strata. When the sand or clay contains much oxyd of iron, the gravel becomes consolidated, and forms a breccia or puddingstone, in which the pebbles are held together by a cement. Beds of gravel and puddingstone are common in the neighbourhood of lofty mountains. The stones and pebbles are formed from the fragments of these mountains, rounded by the agency of water; they are observed to decrease in size according to their distance from the mountains. Probably many of them were formed before the mountains and lower grounds had acquired their present elevation above the level of the sea. At this time, too, many of the valleys might be excavated by marine currents.

It is granted by all geologists that the ocean has once covered our present continents. The disciples of Werner assert that the retiring of the water was gradual. Were we to suppose, with other geologists, that the dry land was elevated by the expansive force of central fires, this power acting upon an extensive portion of the globe might be ages in upheaving the incumbent surface, which would continue to rise until vast fissures were made, through which the subterranean melted matter would be thrown over the mountains and plains then existing, and form the superincumbent rocks of basalt, porphyry, and sienite, that seem to be so nearly allied to volcanic products. While one part of the surface was rising, another part would sink, and form a new bed into which the waters of the ocean would gradually retire. Thus, according to either system, rolled pebbles might be formed by the tides of the retiring ocean, and carried to a great distance from their parent rocks.

According to Humboldt, the extraordinary eruptions by which new islands have been formed since the period of authentic history, are generally preceded by a swelling of the softened crust of the globe. At Kamerni the new island made its appearance above the sea twenty-six days before the smoke was visible. "Every thing indicates that the physical changes of which tradition has preserved the remembrance exhibit but a feeble image of those gigantic catastrophes which have given mountains their present form, changed the position of the rocky strata, and buried sea-shells on the summit of the higher alps. It was undoubtedly in those remote times which preceded the existence of the human race, that the raised crust of the globe produced those domes of trappean porphyry, those hills of isolated basalt in vast elevated plains, those solid nuclei covered with the modern lavas of the Peak of Teneriffe, of Etna, and Cotopaxi." *Humboldt.*

Vast masses of rock near the sea shore are sometimes enveloped in fields of ice, and raised up and transported to distant countries. Ice is specifically lighter than water; every cubic yard will support a stone of one hundred pounds weight: hence we need not be surprised at the insulated blocks of granite that are sometimes found in situations far remote from primary mountains. These blocks have been floated over the ocean, and their angular points and edges defended from attrition, during their passage, by the surrounding ice. In this manner large fragments of granitic and other primary rocks may have been brought upon our coast from Norway and Greenland. In a similar way, in all probability, were the bones of elephants and hippopotami conveyed, without attrition or injury, from the valleys of Siberia to the Icy sea, where they are collected in prodigious heaps, intermixed with sand and ice, and form entire islands of considerable extent. Similar bones are found under the surface, in the banks of all the great rivers of Asia that fall into the Arctic ocean.

It has been noticed, in the preceding chapter, that if a layer or stratum of stone be several yards thick, it is generally denominated a bed. If the bed be so large as to form an entire rock, it may be called a mountain mass.

Fragments of rock are differently denominated according to their size: rounded fragments from the magnitude of a pea to that of a melon are generally called pebbles: if larger fragments or stones exceed five or six feet in length and breadth, they are more properly described as blocks or rocky masses: such is the great stone which nearly chokes up the passage on one side of Borrowdale, called the Bowder stone.

Mountains and hills are relative terms with respect to each other; the highest elevations being denominated mountains, and the lower hills. In the vicinity of Mont Blanc and Mont Rosa, in Switzerland, which are more than five thousand yards high, the mountains in Cumberland and North Wales would be called hills (*collines*), though Snowdon, Skiddaw, and Helvellyn rise nearly eleven hundred yards from the level of the sea, and are ten times higher than Highgate Hill, near London.

In England, if hills rise abruptly, and are more than four hundred yards above the surrounding country, they are generally called mountains. Mountains are sometimes detached, but more commonly are collected in groups or extended in ranges or mountain chains, which traverse whole districts or kingdoms either in a straight or a curved direction. The most extensive mountain chains have a northern and southern direction. It has been observed, that in mountain ranges which have this direction, the steepest declivity is on the western side; and in those which have an eastern and western direction, the steepest side is towards the south. From this rule many exceptions might be stated. I think a more general and invariable rule might be substituted, which I submit to the attention of travellers and geologists. Mountain chains or ranges present the steepest declivities on the sides nearest to the sea. This is remarkably the case in the long chain of the Allegany mountains on the eastern side of America, which are steep towards the Atlantic. On the contrary, the Stony-mountains which run near the north-west coast, and the Andes near the southern Pacific ocean, are steepest on their western side. In ranges of mountains that form the boundaries of extensive vales, through which large rivers flow, the mountains nearest to the rivers have the steepest declivities. The largest rivers have their origin from the sides of mountains which are most inclined to the horizon, and most remote from the sea.

CHAP-

CHAPTER IV.

ON GRANITE AND OTHER ROCKS GENERALLY DENOMINATED PRIMARY.

Geological Classification of rocks:—1. Primary—2. Secondary Metalliferous or Transition Rocks—3. Basaltic—4. Upper Secondary—5. Alluvial—6. Volcanic—7. (Supposed) Fresh-Water Formations.—Granite Rocks, their Composition and Structure.—Granitic Mountains of Europe and America.—Mont Blanc.—Granite Veins.—Situation of Granite Rocks in England.—Rocks of Gneiss and Micaceous Schist described.—Micaceous Schist of Anglesea and the opposite Coast of Ireland.—Crystalline Limestone in Primary Mountains.—Formation of Lime by Animal Secretion.—Origin of calcareous Rocks.—Serpentine Rock.—Verd-antique.—Beautiful Serpentine of Anglesea.—Quartz Rock.—Anomalous Rocks.

IF any rocks can with propriety be denominated primary or primitive, they are those which are most widely spread over the globe in the lowest relative situation, and which contain no remains of organic existence. Werner has enumerated fourteen primary rocks; but as some of these have only been found at present in one place, it appears improper to consider them as distinct orders, unless we arrange every variety of rock in the same manner, and increase the number of orders indefinitely*.

The arrangement here introduced will, I trust, be found both simple and intelligible, and as conformable to nature as the present state of our information will admit. It includes only three principal rocks as primary, granite, with gneiss and mica slate, which are nearly allied to granite, and form an incrustation over it: these never contain organic remains, and they have rarely been observed lying over other rocks in which such remains are found.

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* The system of classification introduced by Werner, was formed principally from observations made in Saxony, and had great merit, as illustrating the geology of that part of Germany: but it has been objected with much reason to the general adoption of the terms he employs, that they were framed to suit a particular theory, before a sufficient number of facts had been collected to warrant its reception. Subsequent discoveries have also proved, that the different classes into which Werner has divided rocks have not the marked and definite characters necessary to constitute a natural system of arrangement. Even the Professor who first introduced into this country the distinctions of transition and flœtz rocks, as a most important discovery of Werner, now states his opinion, "*that the transition rocks may alternate with flœtz rocks, and therefore that the transition and flœtz classes are not separated from each other in the manner generally alleged.*" This admission is the more remarkable, when we recollect the confidence with which these divisions were supported, and the solemn trifling often employed to determine whether certain rocks belonged to the class of transition or flœtz rocks.

CLASS I.

Principal rocks denominated Primary.

1 Granite.
2 Gneiss or slaty granite.
3 Micaceous schist or mica slate.

Subordinate rocks which occur imbedded in the two latter.

1 Crystalline lime-stone.
2 Crystalline hornblende rock.
3 Serpentine.

Serpentine and Hornblende rock are also found in other situations in a superincumbent position*. Beds and entire mountain masses of quartz and felspar occur occasionally in gneiss and mica slate. The quartz is sometimes finely granular, and differs in no respects from crystalline siliceous sand-stone.

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* Since the publication of the first edition of this work, M. Brongniart, a celebrated French mineralogist, has proposed an arrangement in many respects similar to what I had adopted. "Il n'est plus possible d'admettre telles quelles ont été établies les grandes divisions de la succession

CLASS II.

Secondary Metalliferous rocks denominated by some geologists Transition rocks.

1 Argillaceous schistus, slate, clay slate of Werner.

2 Flinty slate. (Hornstone) sometimes porphyritic.

3 Gray wacke and gray wacke (or coarse) slate.

4 Metalliferous lime-stone.

5 Red Sand-stone* also occurs alternating with the above lime-stone and slate: it is frequently coloured red.

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sion des couches du globe." The characters of Brongniart's first class agree with those I had before given in this work. "La première classe renfermerait les terreins dans lesquelles on n'a encore découvert aucun débris de corps organisés dont la structure est crystallisée, et dans la composition desquelles les roches granitiques proprement dites sont dominantes." *Journal des Mines, Mai* 1814.

* This sand-stone has been called by Werner the "old red sand-stone;" but it has very frequently been confounded with sand-stone, whose geological position is very different. See Appendix. It should appear that sand-stone exists in every class of rocks; from those which the Wernerians consider as the oldest, to the very newest formations. The rocks of the first and second class in this arrangement, will comprise all that either commonly contain metallic veins or alternate with metalliferous rocks.

Subordinate to rocks of this class.

1 Gypsum.
2 Imbedded trap.

CLASS III.

Superincumbent rocks of basaltic conformation, or Basaltic rocks.

1 Trap or basalt.
2 Porphyry.
3 Sienite.

Sienite and porphyry are classed by Werner with his primitive rocks. The reasons for arranging them in a separate class are subsequently stated. With many persons the authority of eminent names, particularly of foreigners, has more weight than any reason whatever; I shall therefore add the opinion of Brongniart, that "we are not at present able to find a sienite or porphyry which is evidently primitive." He adopts an arrangement similar to the above, forming a fourth class distinguished by the presence of incumbent porphyry and sienite.

CLASS IV.

Upper Secondary Stratified rocks.

1 Siliceous sandstone.

2 Argillaceous sandstone.
3 Calcareous sandstone and magnesiar earthy limestone.
4 Chalk.

Subordinate beds or strata in secondary r

1 Trap.
2 Gypsum.
3 Rock salt.
4 Ironstone.
5 Coal.

CLASS V.

Alluvial.

1 Clay.
2 Sand.
3 Gravel.
4 Calcareous tufa.

Beds of peat and wood-coal occur i over the sand and gravel.

CLASS VI.

Volcanic rocks.

1 Lava.
2 Pumice.
3 Obsidian.
4 Tufa and volcanic breccias.

A local formation of calcareous strata

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chalk has recently been discovered in the vicinity of Paris, in some parts of the south of England, and also in other situations: these strata contain remains of fresh water fish and quadrupeds. They might constitute a separate class; but they are perhaps too limited to be enumerated among the great masses that form the crust of the globe: they will be noticed in the subsequent chapters.

Rocks of the first class.

Granite is considered as the foundation rock on which slate rocks and all secondary rocks are laid. From its great relative depth, granite is not frequently met with, except in situations where it appears to have been forced through the more superficial covering of the globe. Where granite rises above the surface, the beds of other rocks in the same district generally rise towards it, and their angles of elevation increase as they approach nearer to it. Some writers derive the name from *geranites*, a word used by Pliny to denote a particular kind of stone; others with more probability suppose that the name originated from its granular structure, or the grains of which it is composed. Granite is a hard rock: its constituent parts are the three substances described in the second chapter, quartz, felspar, and mica, which are more or less perfectly crystallized, and closely united together.

The three minerals of which granite is composed vary much in their proportions in different granitic rocks; and often in specimens from the same rock, the crystals are large, or small, or equally intermixed, in one part, and in another part quartz or felspar greatly predominates. Some granites are composed of small grains, and have large crystals of felspar interspersed; these are denominated porphyritic granites. Stones of this kind are common in the foot pavements of London*.

Very small grained granites can scarcely be distinguished from sandstone. In general, felspar may be considered as forming the most abundant part of granite; it is sometimes in a decomposing state, owing to the potash which frequently forms a constituent part of this mineral. It is not improbable, however, that what is considered as decomposing granite, may, in some instances, be the original state of the rock; for various causes may easily be conceived, which would arrest the progress of crystallization in rocks, as we frequently see such an effect to have taken place in the formation of simple minerals.

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* Specimens of Cornish and Scotch granites are not difficult to procure in London, as they are commonly used for paving-stones. In the former the felspar is white, in some specimens it is soft and earthy; the mica appears like glistening scales which have a tarnished semi-metallic lustre. The quartz has a vitreous appearance, and is of a light gray colour. In Scotch granite the felspar has more commonly a reddish brown colour. The mica is not unfrequently black and splendent, and may be divided into thin scales by the point of a penknife: this distinguishes it from hornblende, which is sometimes intermixt with this granite.

Granite is not stratified, but is sometimes separated into tabular masses, which have been mistaken for strata. It is more frequently divided into large blocks, which have a tendency to assume a rhomboidal form. Granite also exists in the form of globular masses, which are composed of concentric spherical layers, separated by granite of a less compact kind, and inclosing a harder central nucleus. These globular masses are three or four yards or more in diameter, and are sometimes found detached, and sometimes imbedded in granite of a softer kind:

probably the detached globes of granite were also once imbedded in a similar rock, which has been decomposed and worn away. This globular structure is not peculiar to granite; it will be again mentioned, and circumstances stated which appear to illustrate its formation. When granite rises high above the surface, it forms lofty peaks and rugged piles, which at a distance resemble immense ruins. According to the German geologists, granite is the lowest of rock formations; but from the observations of D'Aubuisson in Auvergne, and of Humboldt in South America, and from various known phænomena, we have reason to infer that the source of volcanic fires is far below granite*. The highest point at which granite has been seen is the summit of Mont Blanc, in Switzerland, the loftiest mountain in Europe, rising fifteen thousand six hundred and eighty feet above the level of the sea, or nearly five times higher than any mountain in England or Wales. It was first ascended by Doctor Picard in 1786, and afterwards by Saussure, who has published a very interesting account of his ascent. He set out from the priory of Chamouni, from whence the distance to the summit of the mountain in a direct line is not more than two French leagues and a quarter: but owing to the difficulty of the ascent, it requires eighteen hours continued labour, exclusively of the time necessary for repose and refreshment. The first day's journey was comparatively easy, the route being over soil covered with vegetation or bare rocks. The ascent on the second day was over snow and ice, and more difficult: at four o'clock in the afternoon of the same day, Saussure and his attendants pitched their tent on the second of the three great plains of snow which they had to traverse. Here they passed the night fourteen hundred and fifty-five toises (or three thousand one hundred yards) above the level of the sea, and ninety toises higher than the Peak of Teneriffe. The barometer stood at seventeen inches. The next morning they proceeded with much difficulty and fatigue, arising principally from the extreme rarity of the atmosphere, which affected their respiration.* The upper parts of Mont Blanc are above the limits of perpetual snow, and it is only on the sides of the nearly perpendicular peaks and escarpments that the bare rock is visible. They gained the summit by eleven o'clock A. M. "From this elevated observatory," says Saussure, "I could take in at one view, without changing my place, the whole of the grand phænomenon of these mountains, namely, the position and arrangement of the beds of which they are composed. Wherever I turned my eyes, the beds of rock in the chains of secondary mountains, and even in the primary mountains of the second order, rise toward Mont Blanc and the lofty summits in its neighbourhood: the escarpments of these beds of rock were all facing Mont Blanc; but beyond these chains were others whose escarpments were turned in a contrary direction. Notwithstanding the irregularity in the forms and the distribution of the great masses that surround Mont Blanc, and those which constitute the mountain itself, I could trace some features of resemblance not less certain than important. All the masses which I could see were composed of vertical plates (*feuillets*), and the greater part of these plates were ranged in the same direction, from north-east to south-west. I had particular pleasure in observing the same structure in the lofty peak of granite called the *Col du Midi*, which I had formerly endeavoured, but in vain, to approach, being prevented by inaccessible walls of granite. After the second day's ascent, this lofty pinnacle was beneath me; and I fully convinced myself that it is entirely composed of magnificent plates (*lames*) of granite, perpendicular to the horizon and ranging from east to west. I had formerly been induced to believe that these plates were folded round the peak like the leaves of an artichoke; but this was an optical illusion, when seen imperfectly from below: here, where the eye could as it were dart down into the interior structure of the mountain, the plates of rock appeared regularly parallel in a direct line. I was also," says Saussure, "particularly desirous of ascertaining whether the vertical beds were composed of the same substances at their summits as at their bases, where I had so frequently inspected them; and I am perfectly satisfied from actual examination, that they preserve the same nature through their whole extent, and are the same at the summit as below*." *Voyages dans les Alpes, tom.* 4.

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* It seems evident, says Humboldt, that in the Canary Islands, as well as on the Andes of Quito, in Greece, and the greater part of the world, the subterranean fires have pierced through the primary rocks. He further adduces the great number of warm springs, which he has seen issuing from granite, gneiss, and mica slate, in proof of this opinion. *Humboldt's Narrative.*

The inference drawn by Saussure, respecting the vertical position of the beds of granite that compose a principal part of Mont Blanc and the adjoining mountains, is, that they were originally horizontal, and have been subsequently elevated by some tremendous convulsion of nature. The summit of Mont Blanc, he says, must at one time have been more than two leagues under the surface. To the same convulsion he also attributes the position of the escarpments or steep sides of the rocks which face Mont Blanc for a considerable extent, and then turn from it in an opposite direction. This would be the case had the surface of the globe been broken and elevated in the manner he supposes. It may perhaps be doubted whether the vertical position of the beds of rock be not the effect of crystallization on a grand scale. There is a circumstance, however, stated by Saussure, which tends strongly to confirm, if not absolutely to prove, the truth of his hypothesis.

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* The extreme fatigue and exhaustion which Saussure experienced during the ascent of Mont Blanc is supposed to have abridged the life of this active and intelligent philosopher.

Some of the vertical beds of rock covering the granite, contain round pebbles, boulders, and waterworn pieces of the lower rocks. It is impossible to conceive that those rounded fragments could have been placed in a vertical position; for, if they be really pebbles and boulders, the beds on which they occur must originally have been nearly horizontal. Now as these beds are at present placed between others which are also vertical and in the same range, it follows that the whole have been overturned and thrown up at a period subsequent to their formation*.

Gneiss, micaceous schist, and other slate rocks rest upon the sides of Mont Blanc, and on the lower declivities of the mountain are vast masses of limestone.

Many of the mountains in the extensive

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* An opinion has lately been advanced, that the rounded pebbles which occur in rocks are not really waterworn fragments, but original parts of the rock: but Saussure says expressly, that the boulders in the rocks near Mont Blanc are precisely similar to the boulders on the shores of the lake of Geneva. That rocks sometimes include pieces of different kinds of stone, which in fact are original parts of the rock, cannot be doubted; but in such cases there appears a gradual transition, from the substance of the rock into the stone which appears imbedded.

range of the Andes in South America rise much higher than Mont Blanc; but granite has not been found there in a greater elevation than eleven thousand five hundred feet, an elevation exceeded by many of the granite mountains in Europe. The range of the Andes is the seat of active volcanic fires, which appear to have covered the primary mountains with an immense mass of matter ejected by antient and recent eruptions. In Mexico and New Spain also the granite appears to be nearly covered by basalt, porphyry, and lava, ejected from the numerous volcanoes which now exist, or have existed, in those countries.

To this accumulation of volcanic matter the mountains in South America owe their superior elevation. Chimborasso and Cayambo are the highest mountains in the world,—the former rises twenty-one thousand four hundred and forty feet,—but their summits are vast cones composed of volcanic productions covered with snow. Chimborasso is one mile and one hundred and sixty yards higher than Mont Blanc. The general arrangement of the Andes consists, according to Humboldt, of granite, gneiss, mica, and clay slate, as in the Alps; but on these are frequently laid porphyry and basalt, " arranged in the form of regular and immense columns, which strike the eye of the traveller like the ruins of enormous castles lifted into the sky."

In the eastern parts of the United States, and in Canada, granite is seen near the surface uncovered by other rocks, and does not rise to any great elevation. The constant occurrence of granite at a lower level in America than in Europe, is a remarkable geological fact. In Europe the principal mountain ranges are granite; as in Scandinavia, the Alps, the Pyrennees, and the Carpathian mountains. In Asia, granite forms a considerable part of the Uralian and Altaic range of mountains, and it appears to compose the principal mountains that have been examined in Africa.

Granite contains few beds of other kinds of rock, nor is it so rich in metallic ores as gneiss and micaceous schist. Veins of tin most commonly occur in granite, and tinstone is in some situations disseminated through it. Crystals of schorl, topaz, and garnet are sometimes found in this rock, and another mineral before described by the name of hornblende is also common in some kinds of granite, as in that which forms the summit of Mont Blanc. The German geologists will not allow the name of granite to those rocks in which hornblende occurs; but where the three ingredients of granite constitute the principal part of the mass, there appears to be no reason for the objection. And surely if any granite has the title to primary, it is that of Mont Blanc and the mountains in its vicinity: but from the description of it given by Saussure, and from specimens which have lately been sent me from thence, I am convinced that, were we to be guided by the theoretical distinctions of some geologists, we must cease to consider those mountains as primary, from the admixture of talc, chlorite, and hornblende which occurs in the granite of the highest alps.

Granite is sometimes met with not under the slate rocks, but resting upon them in an unconformable position. This granite has been called secondary. It appears allied to the rocks of basaltic conformation, and is said to have been recently found over coal. Secondary granite, sienite, and some kinds of porphyry are, I believe, essentially the same, varying

rying only by the accidental admixtures of hornblende, and by circumstances which have disposed them to be more or less crystalline*. Secondary granite, as it is called, does not possess any well marked characters by which it can be distinguished from primary, if the description given of both by some geologists be correct.

SECONDARY GRANITE.	PRIMARY GRANITE.
1 Felspar commonly a deep red.	1 Sometimes red.
2 Contains garnets.	2 Contains garnets.
3 Not porphyritic; but according to Prof. Jamieson, it is sometimes porphyritic.	3 Is sometimes porphyritic.

The utility of such vague distinctions is not very apparent.

Granite sometimes forms veins shooting up into the superincumbent rocks: this is a fact of some geological importance, as it seems clearly to indicate, either that the granite has been in a state of fusion, the heat of which has softened and rent the upper rocks, and forced up the granite in a melted state into these fissures; or else that the granite and the rocks resting immediately upon it were both in a fluid state at the same time, and are cotemporaneous. A remarkable instance of granitic veins in argillaceous schistus at Touschole in Cornwall, is described in Dr. Thomson's Annals of Philosophy, May, 1814. "The schistus is of a grayish colour, rather hard, but breaks in large fragments in the direction of the strata. The granite is of a fine grain, and the felspar is of a light flesh colour, and contains but a small portion of mica. At the junction numerous veins of granite may be traced from the rock of granite into the schist. Some of these veins may be observed upwards of fifty yards, till they are lost in the sea; and in point of size, vary from a foot and a half to less than an inch. It may deserve notice, that, as the felspar is of a flesh colour, it is impossible for any observer to consider them as quartz veins: one of these large veins is dislocated, and heaved several feet by a cross course. Quartz and fragments of schistus having the appearance of veins are found in the granite veins.

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* According to Brongniart, also, granite, sienite, and porphyry, are frequently observed graduating into each other in some parts of France, and he forms this conclusion: "En étudiant les granites d'un grand nombre de pays pour tacher de distinguer clairement les anciens granites des nouveaux, on trouve presque peu de pays granitiques qu'on puisse rapporter avec certitude à cette ancienne et primitive formation des granites." *Journal des Mines, Mars* 1814.

At one place there is a very curious and satisfactory phænomenon. One of these veins of granite, after proceeding vertically some distance, suddenly forms an angle, and continues in a direction nearly horizontal for several feet, with schistus both above and below it. This appearance most completely destroys one of the theories suggested for the explanation of similar veins at St. Michael's Mount, viz. that a ridge of projecting granite had been left, and clay slate deposited afterwards on its sides."

The parts of England and Wales where granite and granitic rocks occur, are Cornwall, Devonshire, North Wales, Anglesea, the Malvern hills in Worcestershire, Charnwood forest in Leicestershire, and in Cumberland and Westmoreland. The granite near Shap in Westmoreland is porphyritic, containing large crystals of red felspar. There are rolled masses of granite on the banks of Ulswater resembling the granite of some parts of Cornwall, and of the Wicklow mountains in Ireland, but more highly crystalline than the latter. The felspar is in large white and reddish white crystals. The mica is a blackish green, and on the outer parts decomposed.

There is no similar rock in the vicinity known *in situ*. It has all the characters given by mineralogists to primary granite. I am inclined to believe that the same formation of granite which just makes its appearance on the western side of South Britain is continued under the Irish Channel; or if broken there, it rises again in the Isle of Man, and in the counties of Dublin and Wicklow in Ireland. Blocks of granite are found in the beds of some of the rivers in the north-west part of Yorkshire, and in clay-pits in Lancashire and Cheshire, at a great distance from any granite mountains. Most of the granitic rocks on Charnwood forest are of that kind denominated sienite.

The rocks which are most nearly allied to granite, and are frequently incumbent on it in a conformable position, are gneiss, and micaceous schist, or mica slate.

Gneiss may be considered as a kind of slaty granite, in which the constituent parts appear compressed and disposed in layers. Mica is more abundant, and there is less felspar in this rock than in common granite. The mica is generally black, and the felspar white or gray, and yellowish white. Some varieties approach nearly to the structure of granites: others, in which the mica is more abundantly and intimately blended, are more perfectly slaty. It is sometimes waved. This rock has been represented as stratified, I conceive, by a mistake in confounding the stratified with the slaty structure, the latter is occasioned by the quantity of mica and sometimes of talc which it contains, and is the effect of crystallization*.

Beds of crystalline lime-stone, and of hornblende rock, occur in gneiss. It contains most of the metallic ores, both in veins and beds. Crystals called garnets are frequently interspersed in gneiss, but are more common in micaceous schist, which is nearly allied to this rock.

The declivities of granite mountains are covered by rocks of gneiss in many parts of the world. It constitutes the principal rock-formation in a considerable part of Sweden. It occurs in Scotland and Ireland, but is scarcely known in any part of England or

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* The partings or divisions in rocks, which may properly be denominated rents, are distinct from those which are the effect of crystallization, and may be distinguished by their irregularity, roughness, and the indeterminate manner in which they intersect the stone.

Wales. An imperfectly formed gneiss was observed by Mr. Horner on the Malvern hills. I have also seen gneiss brought up from the mines of Cumberland, in all probability part of the wall of a vein. Mountains of gneiss are not so steep and broken as those of granite, and the summits are generally rounded.

The name is borrowed from the German; and, according to Mr. Jameson, was applied by the miners in the vicinity of Freybergh to the decomposed stone that forms the walls of the mine. Werner first ascertained the gneiss, and introduced the name into geological description. Saussure calls this rock "le granit veiné." (*Voyage dans les Alpes.*)

Mica-slate or *Micaceous schistus* is frequently incumbent on gneiss or granite, and covered by common slate: it passes by gradation into both these rocks,—the coarser grained resembling gneiss, and the finer kind, by insensible transition, becoming clay-slate.

Mica-slate is essentially composed of mica and quartz intimately combined; the felspar, which is a principal constituent part of granite and gneiss, occurs only occasionally in irregular masses in this rock. The colour of mica-slate is generally a light gray, inclining sometimes to green or yellow; the finer kinds have a pearly lustre;—in the coarser kind the laminæ of mica are more distinct and splendent. Crystals of garnet are frequently disseminated in mica-slate: it contains occasionally crystals of other minerals. It has a slaty structure, and is often waved and contorted, and divided by thin laminæ of quartz. It sometimes contains beds and laminæ of crystalline lime-stone, or is intermixed with serpentine. Mica-slate also frequently contains beds and veins of metallic ores. The gradation of mica-slate into gneiss and clay-slate, and the transition from granite to mica-slate, may be distinctly seen in some of the rocks near Bray, in the county of Wicklow, in Ireland. I have observed that the beds of mica-slate adjoining the granite are traversed by numerous and large seams of quartz running parallel with the slaty structure of the rock, and increasing in size as they approach the granite. The quartz has a greasy aspect, and is evidently of cotemporaneous formation with the mica-slate and granite.

Mica-slate has a near affinity to clay-slate; and as I have arranged the latter with rocks of the second class, it may perhaps be doubted whether mica-slate should not also have been transferred to the same class. Some recent observations render it probable that not only clay-slate, but what is called gray wacke, approaches sometimes so near to the quality of mica-slate, that it becomes difficult to determine with which rock it should be classed:—this is the case with some of the rocks in Cornwall, formerly classed with mica-slate. No well characterized rocks of mica-slate of any extent occur in England. I have observed a micaceous rock, which may be considered as an imperfect kind of mica-slate near the granitic rocks of Mount Soar hill, but it was covered by wood, which concealed its junction with other rocks. On the western side of Anglesea, near Holyhead, there are numerous rocks of an intermediate kind between mica-slate and talcous-slate. The laminæ are separated by very thin seams of quartz; and I have observed some of them bent and contracted in various directions, as is not unfrequently the case with mica-slate in other districts.

The mica-slate on the opposite coast of Ireland, near Bray, I am inclined to consider as of the same formation with that in Anglesea.

glesea. Probably this rock stretches under the Irish channel, of which it may form the bed in that parallel of latitude. The structure of both rocks is the same, presenting the same divisions by thin laminæ of quartz; but the mica of Anglesea is more combined with talc. Mica-slate abounds in the Highlands of Scotland, and in many alpine districts in Europe.

Gneiss and mica-slate are nearly allied to each other and to granite. Circumstances attending the formation of granite appear to have produced a different arrangement of the component ingredients. This is the more probable, as both gneiss and mica-slate sometimes graduate into granite, and have at other times a porphyritic structure. In some situations the causes which change granite into gneiss or mica-slate have not operated, and we find neither of these substances separating granite from the rocks of the next class.

Mica is sometimes so much intermixt with common sand-stones that they can scarcely be distinguished from mica-slate. Talc supplies the place of mica in some granitic rocks; these are softer than compound rocks containing mica.

It may not be undeserving notice to state that in the vicinity of Woburn, in Bedfordshire, I have observed stones by the road side which had a near resemblance to talcous-slate, both in colour and structure, but were much softer. Had this stone any connection with the fuller's earth in that neighbourhood, a substance which is allied to talcous stones?

The mineral substances imbedded in primary rocks of sufficient magnitude to form mountain masses, are crystalline lime-stone, serpentine, and hornblende.

Crystalline lime-stone.—The most remarkable of these subordinate rocks is crystalline lime-stone, as it is principally composed of calcareous earth, which scarcely exists as a component part of granite, gneiss, or mica-slate. No organic remains are found in the crystalline lime-stone: in primary mountains the structure is granular, the white variety known as statuary marble resembles fine loaf sugar, and is imperfectly translucent; hence it has been called by the French *chaux carbonateé saccaroide.* The colour of primary lime-stone is sometimes yellowish, greenish, or inclining to red. From a mixture of mica it has often a slaty fracture and divides in plates, from which circumstance it has been described as stratified, a term not applicable to rocks that are granular and purely crystalline. It may be further deserving notice that the primary lime-stone or statuary marble frequently contains a considerable quantity of siliceous earth, to which it owes its hardness and durability. White crystalline statuary marble occurs in the Isle of Sky, one of the Hebrides, and many rocks of crystalline marble intermixed with mica-slate and serpentine, are found in different parts of Scotland. Neither in England nor Wales have any rocks of lime-stone been found which possess the crystalline translucent qualities of statuary marble, though very beautiful marbles occur which will receive a high polish; these belong to the lime-stone which will be described in the following chapter.

White marble is procured from Italy, Switzerland, and the Græcian Archipelago. Primary lime-stone exists in beds of greater or less magnitude, which are sometimes so thick as to form entire mountains. It was once supposed that all calcareous rocks and strata are composed of the shells of marine animals, and it cannot be doubted that many of them are entirely formed of these organic remains: but in the beds of primary lime-stone, and even in some of the secondary lime-stones, no vestiges of such remains occur. It may be said that the process by which primary lime was crystallized destroyed all traces of organization, and though it would be impossible to disprove this, yet there is no reason to believe, that lime may not exist as an elementary earth, like silex or alumine, independant of the operations of animal life. It does so exist as a component part of many minerals, and it may have existed in sufficient quantity to form the mountains of primary lime-stone.

It is however a curious but undoubted fact that no inconsiderable portion of the earth's surface has been formed by organic secretion, and the process is still going on rapidly and extensively in the Southern ocean. According to the observations of voyagers, islands and reefs of coral rocks are raised from vast depths in the course of a few years. Thus, millions of minute marine polypi are preparing future abodes for other classes of animals of larger size, and living in another element. From whence do these innumerable

rable zoophytes and shell-fish procure the lime that, mixt with a small portion of animal matter, forms the solid covering by which they are protected? Have they the power of separating it from other substances, or the still more extraordinary faculty of producing it from simple elements? The latter I consider as more probable, for the polypi which accumulate rocks of coral from unfathomable depths have no power of locomotion; their growth is rapid, and the quantity of calcareous matter they produce in a short space of time can scarcely be supposed to exist in the waters of the ocean to which they have access, as sea-water contains but a minute portion of lime.

It is now ascertained that lime and the other earths are compounds of oxygen united with metallic bases, and the brilliant discoveries of Sir H. Davy respecting the metallic nature of ammonia would lead to the conclusion that the metallic bases of all the alkalies and alkaline earths which have many properties in common, may like ammonia be compounds of hydrogen and azote, but differently combined. Now it is well known that hydrogen and azote, which exist as elementary constituent parts of almost all animal substances, may be derived from water and the atmosphere, and should the compound nature of the metallic bases of the earths be ascertained, the formation of lime by animal secretion will admit of an easy explanation.

The beautiful rock called *serpentine* derives its name from its variegated colours and spots supposed to resemble the serpent's skin; its chemical composition has been before described. The colours are most generally various shades of light and dark green, which are intermixt in spots and clouds; some varieties are red. When fresh broken it has some degree of lustre, and a slightly unctuous feel; when pounded the powder feels soapy. It is harder than lime-stone, but yields to the point of a knife, and will receive a very high polish. When serpentine is found intermixt with patches of crystalline white marble, it constitutes a stone denominated verde-antique, which is highly valued for ornamental sculpture. Some varieties of serpentine are translucent, in others there is an appearance of crystallization forming a mineral called schiller-spar. The minerals associated with serpentine are generally those allied to talc. Serpentine is very nearly allied to hornblende, and compound rocks in which hornblende is a predominating ingredient are well known to graduate into serpentine. The softer serpentines appear to be formed of an intimate intermixture of hornblende, with talc or chlorite; a late analysis of one kind of serpentine, gave as much as 48 per cent. of magnesia*. This rock is found in beds in gneiss and slate rocks, and sometimes covers them: according to Brongniart there is in the Higher Palatinate a mountain of magnetic serpentine, in which there is no trace of magnetic iron-stone.

Serpentine forms the upper part of Mont Rosa, one of the highest mountains in Switzerland, and is found in many Alpine districts in Europe; but according to Patrin there is no serpentine in Northern Asia, nor was it observed by Humboldt in the Andes. In the Alps it is observed that the rocks of serpentine lie principally on that side which faces Italy and the coast of Genoa. There is a soft kind of serpentine, sufficiently tenacious to be turned into vessels of any shape, which resist the action of fire; hence they are used for culinary and other purposes in some parts of Switzerland, in Lombardy, and even in Higher Egypt. The use of this stone is of great antiquity, being distinctly mentioned by Pliny; it is called *lapis ollaris*, or pot-stone.

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* A species of serpentine has been discovered in the Pyrennees, formed by a combination of talc with the mineral which Haüy denominates pyroxene (the augite of Werner.) The latter mineral is so closely allied to hornblende both in its chemical composition and its physical qualities, that they ought perhaps to be classed as varieties of the same species, as they differ in little more than the primary forms of the crystals.

In Cornwall serpentine occurs with a micaceous rock lying over granite, and forms part of the promontory called the Lizard Point. It is not met with in any other part of England that I know of, but I have observed rocks approaching the nature of serpentine in Charnwood forest, and in the county of Radnor in Wales.

Beautiful varieties of red and green serpentine occur in the Isle of Anglesea, about six miles from the Paris copper-mine. It is worked for chimney-pieces, columns, &c. by Messrs.

Geo. Bullock and Co., Oxford-street, London, from whom I received the following account: —"The quarries are now working to a considerable extent, and with a fair prospect of ultimate success, although hitherto attended with heavy expense. Like many other productions of our own country, the introduction of this beautiful stone met in the first instance with a very decided opposition; but the splendour and variety of its colours, and the high degree of polish it is capable of receiving by the aid of a powerful steam engine, have recommended it to public favour. It is proved by experience that the colours are indestructible, and on account of its great hardness it cannot easily be scratched or defaced, nor can the polish be injured either by air, moisture, or acids. Columns of any dimensions may be extracted in one shaft. This stone is found in large detached pieces, protruding in some places above the surface of the earth, and it is a considerable depth before the beds are observed to take a regular form. Near it is found the common coarse slate-stone of the country, with occasional veins of copper ore. The serpentine makes its appearance in many parts of the estate; considerable quantities of asbestus lie between the beds." They have since come to a lower bed of greater thickness and extent.

In the absence of a more definite geological description of its situation, the above account may be acceptable. It was not discovered when I first visited Anglesea; but from some specimens shown me by Mr. Bullock this serpentine appears connected with talcous slate*. In the summer of 1811 I was requested to examine some blocks of this stone at Liverpool, which the proprietors supposed were green and red marble. Many specimens have the characters of the precious or noble serpentine; the colours are principally dark green, intermixt with spots and clouds of lighter green, and shining laminæ of schiller-spar or crystallized serpentine. The fracture is conchoidal, and it is translucent at the edges. It resists the point of a copper or brass tool, and breaks with great difficulty. Some varieties contain crystalline lime-stone, but in smaller patches than in the Italian verde-antique; occasional stripes and spots of steatite, asbest, and quartz occur in it. The red is sometimes intermixt with a great variety of other rich colours in the same stone, as black, white, greenish white, and dark green. It may be considered as a most valuable stone for purposes of ornamental architecture, for in beauty and durability it is not exceeded by the costly marbles of Greece or Italy.

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* In passing through Anglesea in 1813 I regretted that I had not an opportunity of examining this rock *in situ*. I had, however, time to inspect a low range of rocks about a mile north of the five-mile stone going to Holyhead, composed of green serpentine, much intermixed with veins of white quartz. The quartz seem also intimately combined with the substance of the rock, which makes it extremely difficult to work or bring to good polish, nor has it the rich variety of colours so conspicuous in the serpentine before described. These rocks rise about thirty or forty feet above the surface, forming detached projecting masses. The rocks in the vicinity appear an intimate mixture of talcous slate and chlorite with serpentine and quartz.

Hornblende, described as a simple mineral in the first chapter, occurs in beds in gneiss; when it occurs in this situation it is called primitive trap, when it has a slaty structure it is called hornblende-slate, and when intermixt with crystals of felspar it is called green-stone. Rocks in which hornblende forms a predominant part will be more particularly described in a subsequent chapter. D'Aubuisson considers the primitive trap near Mont Blanc as granite or gneiss, with an accidental mixture of hornblende; perhaps future observations may confirm this conjecture, and extend it to primitive trap in other districts.

Werner has enumerated four other primary rocks, which I consider as of too rare occurrence or too little known to form distinct orders. These are topaz rock, white stone, gypsum, and quartz rock. The two first, so far from being universal formations or being spread universally over the earth's surface, are not known to occur except in one or two situations. It is therefore extremely absurd to class these as distinct orders, and to omit other rocks which are of far greater extent and importance. Jasper for instance, which is omitted by Werner is said by travellers to form a chain of mountains, on the eastern side of Siberia, of more than one thousand miles in extent, a space far greater than that in which Werner laid the foundation of his system. Had the professor been originally placed in Siberia, instead of Saxony, we should doubtless have had a *Jasper Geognosy*, to which his disciples would have bowed with as much superstitious reverence as to the *Geognosy* of Freybergh.

Felspar also sometimes forms entire mountains, and might for the same reason be entitled to constitute a distinct order of rocks. Certain causes appear to have operated locally, and separated the quartz and felspar of granite into masses of vast extent. The beautiful conical mountains called the greater and lesser Sugar Loaf, in the county of Wicklow, are composed of quartz; it extends also across the upper part of the picturesque glen called the Dargle, where I had an opportunity of examining it. The quartz has somewhat of a greasy aspect, and appeared similar to that which forms numerous veins in the mica-slate near its junction with the granite in the adjoining mountains to the north. I therefore am inclined to infer that it is of cotemporaneous formation with those veins. According to the observations of Dr. Macculloch, the quartz rocks of the island of Jura, and many parts of the Highlands, present evident indications of being composed of fragments and rounded pieces again united, and is in fact a species of quartzose sand-stone. Topaz rock is a granitic rock containing principally crystals of quartz, a mineral called schorl, and topaz; it has been found only in one situation, near Auerbach, in Saxon Voightland. What is denominated white-stone consists of white felspar, white quartz, and garnets. Gypsum occurs occasionally among the Alps in Switzerland; but, according to the recent observations of D'Aubuisson, many of the mountains in that country which have hitherto been denominated primary contain organic remains, and must be classed with secondary rocks. If all the varieties of rock found amongst the primary were arranged in distinct orders, the number would be indefinitely extended, and the science encumbered with a list of names which would be of little use. It is, I conceive, better to class these varieties under one head as anomalous, and to describe their peculiarities whenever they occur.

The metallic ores peculiar to different primary and transition rocks will be subsequently enumerated.

Primary mountains being principally composed of siliceous earth, are unfavourable to vegetation, and from their extreme hardness and precipitous declivities seem doomed to eternal barrenness; but in the lapse of ages lichens and mosses attach themselves to their sides, and by their decay accumulate soil for vegetables of larger growth. Water wears down the hardest stones on the earth's surface by continued attrition. It also permeates the fissures of rocks, where it is expanded by frost, and breaks down large masses in a single night. The progress of disintegration is slow but certain, and the agency of air, of water, of heat, and light, is insensibly but constantly operative in "converting stones into bread," or, in other words, in preparing soils from the most sterile rocks for the support of vegetable and animal life*.

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* Plate I. fig. 1, is supposed to represent the section of a country, where granite is seen above the surface at *a*, gneiss at 2, mica-slate 3, slate and other transition rocks 4 and 5, secondary rocks 6. In passing from secondary rocks to the primary, it frequently happens that the intermediate rocks 4 and 5 occupy an extent of many miles or leagues, and sometimes cover a whole district. 6 represents a rock imbedded in slate.

CHAPTER V.

ON SLATE AND OTHER TRANSITION OR LOWER SECONDARY ROCKS.

Rocks of this Class contain certain Organic Remains—are commonly Metalliferous.—Argillaceous Schistus or Slate.—Varieties of Slate.—Gray-wacke.—Metalliferous Lime-stone.—Extensive Caverns in this Lime-stone.—Amygdaloid of Derbyshire.—Opinions respecting its Formation.—General View of Primary and Transition Mountains.

LEAVING the rocks denominated primary, we come to the next class called transition or intermediate. These rocks are particularly distinguished as being the lowest in which fossil remains of animals or vegetables are found; they may be regarded as ancient records imprinted with the natural history of the first inhabitants of the globe. We learn from the organic remains and impressions which these rocks contain, that zoophytes and shell-fish, which are considered as forming the lowest link in the scale of animal creation, were the first that received the gift of life. In the rocks above these, remains of animals occur, which possessed a more complex organization, with the added faculties of sight and locomotion. It is also deserving notice, that the organic remains in the rocks of this class belong to species of animals that no longer exist on the earth, and the few impressions of vegetables are observed by botanists to be those of monocotyledons.

Geologists have been frequently perplexed in attempting to determine whether certain rocks belonged to the transition class. The uncertainty arose principally from placing argillaceous schistus in the class of primary rocks ; and the disciples of Werner are obliged to introduce the theoretical terms of newer and older primary slate, and newer and older transition slate, to adapt their system to the different situations in which slate rocks occur.

The following arrangement includes in the same class the lower secondary rocks, which are either commonly metalliferous, or are subjacent to rocks which contain metallic veins. A character much more definite than perhaps any other that could be named to designate this class. Some instances occasionally occur of metallic veins shooting into the upper secondary rocks,—but these are very rare.

1 Argillaceous schistus, slate, or clay-slate of Werner.
2 Flinty slate.
3 Subcrystalline lime-stone, metalliferous.
4 Gray-wacke and gray-wacke slate.
5 Red sand-stone, called the old red sandstone and two subordinate rocks, trap and gypsum.

Argillaceous schistus, clay-slate, or roof-slate, is very generally spread over alpine districts; it rests on mica-slate, gneiss, or granite. That slate which lies nearest the primary rocks has a more shining lustre than the other, and partakes more of the crystalline quality of mica-slate. As this rock recedes from the primary, it more frequently contains organic impressions. Its colours are various shades of gray, inclining to blue, green, purple, and red. Some kinds of slate split into thin laminæ, which are well known as forming roof-slates. The external structure, or that of the mountain mass, is tabular, consisting of tables or plates of various degrees of thickness, which generally are much elevated. This rock is always represented as stratified; but in this respect it resembles gneiss and mica-slate, and the slaty and tabular structure are, I conceive, the effects of crystallization, depending on the nature of its constituent parts. In the slate-rock at Charnwood forest the slaty laminæ make an angle of sixty degrees with the principal seam by which the rock is divided. Almost all the rocks of this district have a tendency to assume regular pyramidal forms.

Slate-rocks vary in their quality, and pass by transition into flinty slate, which appears to differ from common slate by containing a greater proportion of siliceous earth. Talcous and chlorite slate contain an intermixture of talc or magnesia. Drawing slate is stated to contain 11 per cent. of carbon. Whet-slate or Hone is also a variety of slate. Beds of different rocks occur in mountains of slate, they are frequently intersected by veins of quartz and by veins and beds of metallic ores. Carbonaceous matter is first discoverable in slate-rocks, and increases as we approach the secondary strata. Vegetable impressions are found in some slate-rocks in very elevated situations, as in the vicinity of Mont Blanc.

Those varieties of roof-slate are preferred for the covering of buildings which have the smoothest surface and split into the thinnest plates; they are, however, frequently made too thin to be durable, and too light to resist the force of the wind during storms.

Quarries of slate are worked extensively in Westmoreland, Yorkshire, Leicestershire, North Wales, Cornwall, and Devonshire. The Yorkshire slate contains cubic crystals of pyrites, and is sometimes covered with thin pyritic configurations resembling trees, hence called ‘ dendritical.’

Mountains of slate are seldom so precipitous as those of granite; they may be distinguished at a distance by their outline, which is less broken and craggy. On a nearer approach, they are seen covered with verdure on their declivities, as they contain less silex and a more equal admixture of the earths favourable to vegetation.

Flinty slate, as I before observed, differs from common slate by containing a greater quantity of siliceous earth, and as its name implies it partakes of the nature of flint.

Slate and flinty slate pass into each other, and frequently alternate. When the latter ceases to have the slaty structure, it becomes horn-stone, or what the French denominate petro-silex. If it contain crystals of felspar, it becomes horn-stone porphyry: all these varieties may be observed alternating with each other in the same rocks in Charnwood forest, and in North Wales and Cumberland.

A rock to which the Germans have given the barbarous name of *grau-wacce* (gray-wacke) belongs to this class. Gray-wacke is composed of clay-slate, containing imbedded grains and fragments of other minerals, particularly of indurated clay-slate, quartz, and flinty slate. According to the size of the grains or fragments, it is denominated fine or coarse grained gray-wacke. The finer grained varieties acquire a slaty structure, and are called gray-wacke slate, which is only a coarser kind of clay-slate. Some varieties contain so much mica as to pass into mica-slate. Gray-wacke alternates with vast beds of lime-stone, flinty slate, and trap. It frequently contains metallic veins and beds. The grains or fragments in some kinds of gray-wacke are of such a size as to approach to the nature of a conglomerate rock or pudding-stone.

Some geologists, who once considered the mixture of mechanical depositions or fragments as a marked character of transition rocks, now consider such apparent fragments to be the result of crystallization, as they are sometimes observed to graduate into the basis of the rock in which they are imbedded. See Professor Jamieson on the Mineralogy of the Pentland Hills, and on Conglomerated Rocks,—Memoirs of the Wernerian Society, vol. ii. part 1. The advocates of a different system might with equal probability say that these imbedded pieces were real fragments partially softened, and fused by internal heat, and thus blended with the base, particularly as the organic remains in some of these rocks prove that they must have been formed at different periods, whatever may have been the process by which they subsequently became imperfectly crystallized.

Gray-wacke is nearly allied to clay-slate, and the finer kinds of gray-wacke-slate pass into clay-slate, and are not to be distinguished from it. These rocks are commonly intersected by veins of quartz, and are rich in metallic ores.

Gray-wacke is met with on the western side of England, and in Wales. In the north part of Radnorshire is a lofty range of mountains composed of gray-wacke, which on the eastern extremity graduates into sand-stone, and on the western, into roof-slate. When engaged in a mineralogical examination of some estates in that county, I explored a section of this rock not less than thirteen hundred feet in thickness in a deep ravine which intersected a lofty mountain near New Radnor; it was distinctly stratified, and contained no beds of foreign rock that I could discover in any part from the summit to the base. In some parts it had a tendency to a rhomboidal form. Gray-wacke was not observed by Humboldt in the Andes.

The lime-stone which occurs, alternating with rocks of slate and gray-wacke, has been called transition lime-stone. The present arrangement includes in the same class the vast beds of mountain lime-stone which occur resting on, or alternating with red sand-stone or gray-wacke. The lower beds of this rock in the alpine parts of England, agree in many of their characters with the former, and as it is now admitted that there is no well marked difference between the transition rocks, and what were called by Werner the lowest flœtz rocks, it is useless to retain vague distinctions, which only serve to support unfounded hypotheses. The transition lime-stone and mountain lime-stone agree also in the important characters of being rich in metallic veins, and in containing beds of trap and amygdaloid. They both exist in masses of vast thickness, and often form entire mountains, presenting lofty perpendicular cliffs and deep ravines. This lime-stone is less crystalline and more compact than the primary. The lower beds often exhibit a variety of colours and are sometimes black and gray. The upper beds are more distinctly stratified than the lower, and abound more in marine petrifactions. The organic remains belong to animals no longer existing on the globe. The variegated lime-stones of Devonshire and Cornwall may be considered as the lower transition lime-stone of some geologists, and the lime-stone of Craven in Yorkshire, and the peak of Derbyshire as the alpine lime-stone. The lowest beds of lime-stone rocks in the latter districts are of vast thickness, are compact or finely granular, and contain few organic remains, compared with the upper. It is in these lower beds of mountain lime-stone, that enormous natural caverns frequently occur, such are the well known cavern near Castleton and Pools hole near Buxton in Derbyshire, and Yordas cave under Whernside in Craven: Gordal scar and Weathercock cave in the same district, cannot properly be called caverns, as they are open to the day, but the latter was probably once a cavern of which the roof has fallen in. In all these caverns and others that I have observed in this lime-stone, there is a stream of running water, which is more or less copious in rainy or dry seasons, and I am inclined to believe that the caverns have been formed by the agency of water percolating through natural fissures, and in the lapse of ages excavating the softer or more broken parts of the rock. The prodigious force with which these subterranean streams rush through the openings of some of these caverns, after continued rains, suggests the probability of this mode of formation. The whole of that enormous mass of lime-stone in Craven, from

Ingleborough and Whernside to Gordal is intersected by perpendicular fissures which are narrow at the top and become wider as they descend, through which the water may be heard to run at a vast depth below. These unseen but ever active streams are slowly but progressively wearing down the internal parts of these calcareous mountains and depositing them in the sea.

The metalliferous lime-stone of Derbyshire contains thick beds of trap or basalt. In one or two instances the Derbyshire trap has been observed to assume the columnar structure. Other beds contain cavities filled with calcareous spar: they are provincially called toad-stone, the amygdaloid of mineralogists. Some varieties have a near resemblance to lava, and were supposed by Mr. Whitehurst to have been forced between the beds of lime-stone when in a state of fusion. Were we to admit their igneous origin, a more natural supposition, I conceive, would be that they were formed at distant periods of time, by successive eruptions of submarine volcanoes, when these mountains were covered by the ocean; for it cannot be doubted that they were once under the sea. From recent observations, we have reason to believe that the agency of submarine volcanoes is very extensive. Probably many of the differences observed in volcanic products and basaltic rocks, were occasioned by the different circumstances to which they were exposed after their eruption, on the dry land, or under the incumbent pressure of the waters of the ocean.

The trap or green-stone of Cornwall, which occurs in transition rocks, has no characters by which it can be distinguished from that found in primary. Gypsum, or lime combined with sulphuric acid in a crystalline state, has been occasionally observed in transition mountains, but is of too rare occurrence to merit a particular description in an introductory work.

The red sand-stone called by Werner the old red sand-stone*, is composed of grains principally of quartz, and often coloured red by the oxyd of iron. It forms beds of vast thickness, the upper and lower parts frequently vary much in quality and fineness of the grain. This rock commonly rests on coarse slate, or gray-wacke. It occupies a considerable part of the north-western counties of England, from Cumberland to Lancashire, Cheshire, and Shropshire. The metalliferous lime-stone of Durham and Northumberland rests upon this rock. See the chapter on the geology of England. It is very indistinctly stratified, and is remarkable for cutting off the coal, for whenever it occurs, all search for coal beneath it is useless. There are however some of the upper secondary sand-stones alternating with coal, which very nearly resemble this rock both in colour and other external characters. The rocks associated with the red sand rock, terminate the series of transition rocks, containing metallic veins, and the more antient organic relics of marine animals. The strata which immediately cover them abound principally in impressions of vegetables, and contain few remains of animals of any kind. It is however, well deserving notice, as marking the changes which the surface of our planet has undergone, that after a succession of numerous beds and strata containing almost exclusively vegetable remains, whose total thickness is in some situations more than one thousand five hundred

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* In the arrangement of Werner this is the lowest of the fletz rocks; but as it is not distinctly stratified, and sometimes alternates with transition and metalliferous rocks, I have classed it with them.

dred yards, we again meet with calcareous rocks, abounding in remains of marine animals but different from those in the lower rocks. Before proceeding to describe the other secondary rocks, it will be proper to notice a class of rocks which have no regular order of succession, but which appear to have been forced through and spread over the more regular beds of rock, in various parts of the world; these are the rocks of basaltic conformation, including porphyry, sienite, and trap. They occur among rocks of the preceeding and subsequent classes.

Primary and transition rocks constitute the loftiest mountains and mountain ranges in every part of the world, except such as are of volcanic origin. They are the repositories of the most valuable metallic ores, and they supply us with materials for durable architecture and sculpture. They have besides the most important uses in their physical influence on the climate and habitable condition of the globe. They collect and condense clouds and vapour; hence springs and rivers have their origin, and are precipitated to fertilize distant regions. The loftiest mountains in the torrid zone are covered with eternal snow, and serve to cool and equalize the temperature of countries which would otherwise be unfit for the abode of man. They arrest the progress of the winds, and cause currents in the atmosphere, by which it is rendered pure and salubrious. Nor ought we to omit that they adorn and diversify the surface of the globe with all those picturesque and magnificent scenes which afford such exquisite delight to the lover of nature;—scenes that tranquillize the mind, and elevate the imagination to a better world.

> "————the inexpressive strain
> Diffuses its enchantment. Fancy dreams
> Of sacred fountains, and Elysian groves,
> And vales of bliss." AKENSIDE.

The reasoning faculty awhile yields to these charming illusions; or, as the same poet expresses it,

> "————The intellectual power
> Bends from his awful throne a wondering ear,
> And smiles."

Surely it may be regarded as a proof of benevolence and design in the constitution of the universe, that the Author of nature has framed our senses and faculties to receive such delightful impressions from the inanimate objects with which we are surrounded.

CHAP-

Fig. 1.

Fig. 1. Basaltic configurations.

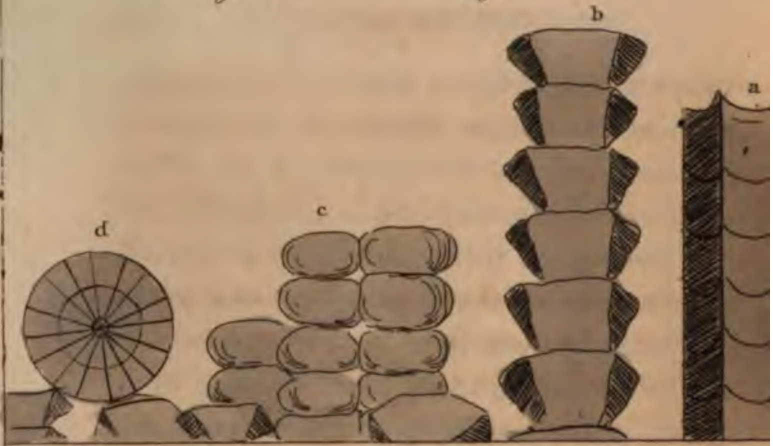


Fig. 2.

Fig. 2. Basalt Dyke, Shropshire.

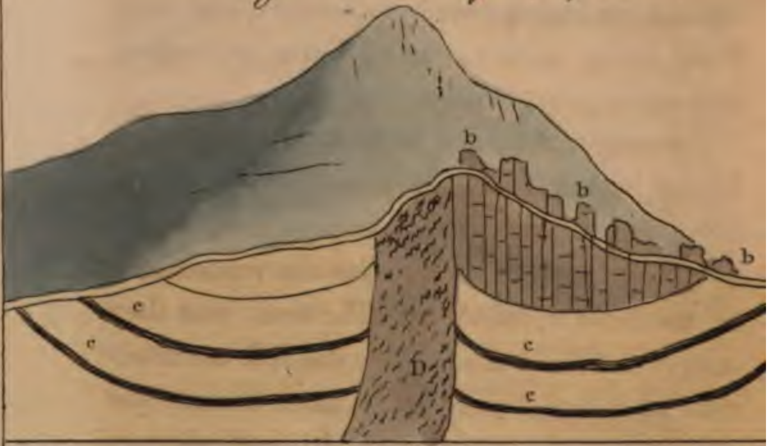
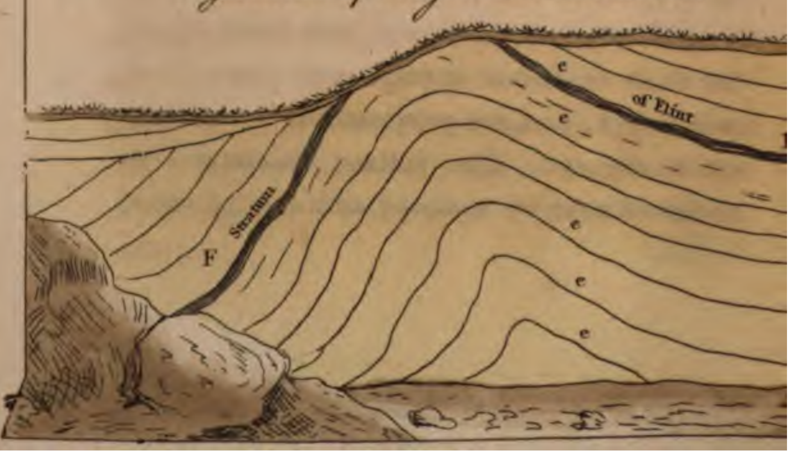


Fig. 3.

Fig 3. Strata of Magnesian Limestone.



CHAPTER VI.

BASALTIC ROCKS, PORPHYRY, AND SIENITE.

Position of these Rocks, their Gradation into each other, and resemblance to Volcanic Products.—Sienite, Green-stone, Basalt, Amygdaloid, and Porphyry described.—Neglect of Porphyry by modern Architects.—Various Formations of Porphyry.—Columnar and Globular Basalt.—Experiments illustrating their Formation.—Basaltic Rocks of Auvergne and Sicily.—Basaltic Columns of Ireland and the Scotch Hebrides,—Basaltic Rocks extending in the same parallel of longitude.—Speculations of different Geologists.—Theory of Werner.—Observations of Sir G. Mackenzie in Iceland.—Remarkable appearance of Basalt at the Clee Hills in Shropshire and in the County of Durham, illustrating the origin of Basalt.—Basaltic Columns of Teesdale.

THE rocks which form the subject of the present chapter are particularly distinguished by their structure and position, and by other geological characters which compel the mind to speculate respecting their origin. The manner in which they cover other rocks was described in the second chapter; but it may afford a familiar illustration if we suppose a set of volumes a little inclined and leaning on each other, to represent the conformable position of primary and transition rocks; and a single volume of another set introduced between them, to represent an imbedded or subordinate rock: now if a large book be laid flat over these, it will represent the position of a superincumbent basaltic rock. This, I have before observed, is what the German and Anglo-German geologists denominate the "unconformable overlying position."

Granite is generally believed to form the foundation rock on which the superficial parts of the globe rest; but it is not improbable that granite also covers lower rocks in an unconformable position. It is sometimes found in this position upon other rocks, and is then called by the Germans secondary granite, which nearly resembles sienite, one of the rocks belonging to the present class. The transitions by which granite passes into sienite, and the latter into porphyry, trap, and basalt, are gradual, and in some rocks almost imperceptible. These changes are principally effected by an intermixture of the mineral already

ready described under the name of hornblende. This substance forms the connecting link between granitic rocks and those which are of undoubted volcanic origin. It occurs in some granite, and when the quantity increases and supplies the place of quartz, it forms the rock denominated sienite, from Sienne in Upper Ægypt, where it abounds, and was employed for purposes of architecture and sculpture by the Ægyptians and Romans. In sienite the felspar is generally red, and the hornblende black or dark green. When hornblende predominates and the crystals are small, it is called green-stone, by the Germans *grunstein*. In green-stone the felspar is paler, and frequently white. Transitions from granite to sienite and green-stone may sometimes be observed in the same block, as I have noticed at Charnwood forest in Leicestershire. According to Brongniart, granite and gneiss alternate with, and pass into porphyry and sienite; in the department of La Manche, the sienite there reposes on coarse slate like that in Leicestershire. A transition from sienite to green-stone may be observed in the colossal Ægyptian sculpture in the British Museum. Sienite and green-stone are met with in Cornwall, Wales, and Cumberland. Markfield Knowl, a hill on Charnwood forest, is composed of a most beautiful red and dark green sienite; on the upper part of the hill it lies in detached pyramidal blocks.

Rocks in which hornblende forms a predominating ingredient, have been denominated trap rocks, from the Swedish word *trappa* a stair; as these rocks frequently divide into regular forms resembling the steps of a staircase. A variety of names have been given to trap rocks by different geologists; but they may be considered as essentially the same,—differing only in their mode of aggregation, being more or less perfectly crystallised. The French, after the Abbè Haüy, fancifully denominate them '*roches amphiboliques.*' The term trap having been previously introduced, may serve as a generic word to designate the rocks of this order called green-stone, basalt, amygdaloid, and whin-stone.

When green-stone becomes compact by an intimate intermixture of its constituent parts, it forms basalt, which differs little from compact lava. The component ingredients of these rocks were stated in the second chapter. Greenstone and basalt may not unfrequently be seen passing into each other in the same stone, as D'Aubuisson and Dolomieu have previously observed. Trap rocks are seldom so hard as to strike fire with steel. They all contain a considerable quantity of iron, and pass from a greenish black or brown by various shades to an ash-gray colour; they yield an earthy smell when breathed upon, and are fusible with the blow-pipe, forming a black glass. Trap rocks which have a slaty structure are called green-stone slate. If basalt contain cavities or vesicles filled with different mineral substances, it is called amygdaloid, which has a striking resemblance to porous lava. Agates are frequently found in the cavities of amygdaloid. The amygdaloid of Derbyshire is provincially called toad-stone, the cavities being generally filled with calcareous spar, which gives it a spotted appearance, supposed to resemble the back of a toad.

Porphyry derives its name from the Greek word signifying red, as the porphyry used by the ancients was most frequently of that colour. The term porphyry is very vague, being applied to all rocks that have a compact base or ground in which crystals of any kind are imbedded and distinctly visible. Thus, according to the kind of stone in which the crystals occur, the porphyry takes its more appropriate name, as horn-stone porphyry, clay-stone porphyry, pitch-stone, and obsidian porphyry*, &c.

The base of porphyries is generally allied to trap, and is fusible. The crystals are either quartz or felspar, but more commonly the latter, forming four-sided or six-sided prisms, whose length is greater than the breadth. Pitch-stone and obsidian nearly resemble opaque glass, in the latter the vitrification is perfect. These substances occur in volcanic rocks, and in the neighbourhood of volcanoes, in situations that leave no doubt of their igneous origin: hence the probability is increased that the other kinds of porphyry which accompany them have had a similar formation.

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* In fact the terms porphyry and amygdaloid rather represent a mode than a substance, and convey no precise idea, unless the nature of the base be specified; such rocks would be more correctly described as porphyritic or amygdaloidal.

In the Andes and in Mexico, as was before stated, enormous masses of porphyry, basalt, and lava, cover the granite and slate. According to Professor Jamieson, porphyry may be traced extending from Norway to the borders of the Black Sea. It has also been observed in Upper Ægypt and Siberia. Porphyry occurs on the western side of England, and at the Cheviot Hills in Northumberland, and in North Wales. Porphyry is also found at Charnwood forest in Leicestershire.

As porphyry exists in masses and blocks of enormous size, and is very durable, it was highly prized for architecture by the nations of antiquity. No better reason can be offered for the neglect into which porphyry and granite have fallen in modern times, than their extreme hardness, which increases the expense of working them; but surely it is an ill-placed parsimony to employ perishable materials for public edifices that ought to endure for ages, and perpetuate the memory and the glory of the times in which they were constructed. All the public buildings and bridges in the metropolis of England, of modern date, are built of Portland-stone, a species of lime-stone which is easily acted upon by water. The sculpture and the figures in alto relief of this stone at Somerset House are rapidly perishing, and the magnificent bridge of Black Friars is fast hastening to decay in the very life time of its founder*.

The extreme hardness of some kinds of porphyry may be illustrated by a circumstance mentioned by Mr. Williams respecting Ben Nevis, the highest mountain in Great Britain, which he describes as composed of granite and porphyry. "On the north-east side, at the bottom of a frightful precipice of five hundred yards, there is a deep gulf, which has a smooth and solid pavement of granite, upon which has fallen a fragment of several tons weight from four hundred yards perpendicular height; but instead of being dashed to pieces by the inconceivable force of the shock, it is whole and entire†."

At the time when Mr. Williams wrote, the difference between granitic and porphyritic rocks was not well understood. Col. Imrie has lately published a description and section of Mount Battock, situated like Ben Nevis, in the range of mountains called the Grampian hills, by which it appears that granite occupies the central and highest parts; on the sides are laid gneiss, mica-slate, and slate, and lower down various rocks of trap and porphyry. The base is covered with sand-stone, the strata of which rise towards the mountain at a very high angle of elevation.

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* I have attempted to direct the attention of the public to this subject in an "Essay on the Selection of Stones for the purpose of durable Architecture," which appeared in the Monthly Magazine for June 1811, and has since been reprinted in America.

† Williams's Mineral Kingdom.

Some geologists have described four formations of porphyry; but Humboldt, who has made more extended observations on volcanic and basaltic rocks than any philosopher who has preceded him, admits that the classification of porphyry is exceeding difficult; for though geologists describe four formations of porphyry, he observes that "they frequently present transitions into each other, but never any into the rocks on which they repose." Porphyritic rocks occur in gneiss and mica-slate;—such has been called primitive porphyry, from occurring in this situation. The porphyry which alternates with sienite, Humboldt says, probably belongs to transition rocks. It contains beds of pitch-stone and obsidian, and even of granular lime-stone, as at Meissen in Saxony. It is extremely rich in metals; and is found at Guanaxato Regla, and other situations in Mexico, and in Norway, Sweden, and Hungary. "It is this second formation," he says, "which appears to have been the centre of the oldest volcanic revolutions.. The third formation belongs to the old sand-stone which forms the basis of the Alpine lime-stone. It contains amygdaloid inclosing agates, and sometimes covers strata of coal." The fourth formation of porphyry is basaltic, and destitute of quartz. In America it is often intermixed with augit and olivine:—it accompanies green-stone, basalt, and clink-stone:—it occurs at Chimborazo in the province de los Pastos, near Berne in Switzerland, and at the Puy de Dome in Auvergne.

Porphyry, sienite, and trap have frequently a columnar structure, and form ranges of lofty natural columns which strike the observer with astonishment by their magnitude and regularity, though in reality they are not more extraordinary than the regular crystals which we meet with in every part of the mineral kingdom. The globular structure is not uncommon in these rocks; and even mountains of trap or porphyry, in which no particular structure can be observed when whole, often present the globular structure when the parts are decomposing, and round balls fall out which were harder than the other parts of the rock. It has been before observed that granite has sometimes a similar structure, and is composed of balls consisting of concentric spheres of stone encircling each other. De Luc says that in the granite mountains of Silesia he saw piles of these globes of granite, which at a distance resembled gourds or melons; but I conceive he is mistaken in supposing they had once a rhomboidal form. An experiment of Mr. G. Watt throws much light on the formation of the globular structure of basaltic and other rocks. He fused seven hundred weight of trap and basalt in a furnace, and kept it in that situation several days after the fire was reduced. It melted into a dark coloured glass with less heat than was necessary to melt the same quantity of pig iron. In this glass small globules were formed, which disappeared again; and as the cooling proceeded the mass changed from a vitreous to a stony substance, other globes were again formed within the stony mass, which continued to enlarge until their sides touched and pressed against each other, by which pressure the globes formed polygonal prisms. If part of the mass were cooled before the globular structure was destroyed, these globes were harder than the surrounding stone, and broke in concentric layers. In this manner, in all probability, the balls of basalt and porphyry which fall out of decomposing rocks were formed; they derived their superior hardness from the crystalline arrangement of the particles when in a melted state. When these globes were enlarged by a continuation of the same process, they pressed on each other, and formed prisms in a similar manner to the globules in the experiments of Mr. Watt. The upper prisms pressing by their weight upon the lower, formed concavities or sockets, into which they would sink, and remain jointed together or articulated. Such is frequently the structure of basaltic columns. It had been previously proved by Sir James Hall, and has since been amply confirmed, that basalt and lava, when melted and cooled rapidly, form a suba substance resembling glass; but if the same glass be melted again and cooled slowly, it assumes its original stony texture; and if the diminution of temperature be very gradual, this stony substance will have a prismatic or columnar form, like that of basalt rocks.

Porphyry and sienite commonly cover primary and transition mountains; trap or basalt, secondary hills. An extensive formation of porphyritic and basaltic rocks exists nearly in the same parallel of longitude, from the Canary and Madeira Islands to Ireland, Scotland, the Hebrides, and Iceland. The northern and southern extremities are at present the seat of active volcanoes, which are probably the unextinguished remains of extensive subterranean and submarine fires. It has been observed that large whin dykes, or those rents of the earth's surface which are filled with basalt, have generally a direction inclining to the north and south. The most extensive mountain chains have the same direction. If mountains owe their elevation to the expansive force of subterranean heat, it should appear that the crust of the globe is more disposed to split longitudinally than in the opposite direction. The Andes in South America, with the continuation of the same chain of mountains through the Isthmus of Darien, and along the western side of North America, to the Arctic circle, is the longest mountain range on the globe; it is also the seat of volcanic fires, extending in the same direction more than eight thousand miles. D'Aubuisson states that the ancient volcanoes in Auvergne run in a line from north to south. The basaltic ranges of that district, which can be traced to their source, seem to have taken this direction. Two leagues to the west of Clermont, near sixty volcanic mountains are seen ranged in the same line: hence he is led to infer that there was a bed of combustible matter in that direction, which was the source of these volcanic fires. The account which D'Aubuisson gives of the basaltic rocks of Auvergne is extremely interesting. He had previously written to disprove the igneous origin of basalt; but at that time he had never seen a volcano or a current of lava. At the invitation of the National Institute of France he undertook the examination of this province, and returned fully convinced that the ranges of basalt which cover a considerable part of it were formed by volcanoes, the remains of which are still visible.—Dolomieu, who had spent many years in the examination of volcanic countries, also ascribes a volcanic origin to the basalt of Auvergne. (Brochant, Minéralogie, tom. ii. 619.) An English traveller just returned from Auvergne, says, "On examining the basalt of this country, and comparing it with the blocks of granite and schist which every where accompany it, and have undergone the action of fire in every degree up to a substance no way distinguishable from basalt except in form, I think it impossible to doubt the agency of fire in its production. These antediluvian volcanic remains extend over a space of several thousand square miles. The basalt was probably a stratum of granite, fused by a subterranean fire, without being ejected from its native bed, and acquired its prismatic form from the circumstances attending the cooling. The conical hills which form the chief ornament of this interesting and romantic district appear to be rocks of basalt, which have crumbled and shivered down until they have assumed their present shape. I ascended one of these cones called La Tour d'Auvergne from an old castle on its summit, which was evidently of this character. Among the scoriæ, about three leagues from Clermont, are the charred remains of many trees. No appearance of a crater was to be observed any where." *Notes on a Journey through France, by Maurice Birkbeck*[*].

Though there may be no elevated craters similar to those of recent volcanoes, D'Aubuisson expressly informs us that the currents of basaltic lava may be traced for many miles from the bottom of several of the conical hills in that district over the adjacent plains, and that these currents have sometimes reached the adjacent valleys, and followed their course for three or four leagues. He also says, on the summit of some of these conical hills there are hollows resembling craters. Ferrara, Professor of Natural Philosophy at Catania, asserts that at the Motta in Sicily, where there is a range of basaltic columns two feet in diameter, covered by red drosses and puzzolana, an aperture was lately made by the peasants under the columnar basalt; and when the hand was introduced, a sensible heat was perceived, and the hand smelt of sulphur. Remarkable basaltic columns occur in other parts of Sicily, covered with massive lava of the same substance, which is often continuous with the columns.—Few countries in the world present more magnificent basaltic rocks than the north part of Ireland, and some of the Hebrides: probably these are connected under the ocean, and have had the same origin.

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[*] This small pamphlet, under the unassuming title of Notes, contains much valuable information, particularly on the agriculture of France, and also more materials for reflexion, than are to be met with in most of the modern quarto volumes of travels. On comparing it with them the observation of an eminent philosopher presents itself to the mind: (il n'y a que deux sortes des hommes, ceux qui pensent et ceux qui ne pensent point,) accompanied with the regret, that so many of our modern travellers, though dexterous bookmakers, belong to the latter class.

The Giant's Causeway constitutes a small part of a vast basaltic range along the north coast of Ireland, in the county of Antrim. The promontory of Fairhead and Borgue, in the same range, are situated eight miles from each other: these capes consist of various ranges of pillars and horizontal strata, which rise from the sea to the height of five hundred feet, and from their abruptness are very conspicuous, and form a pile of natural architecture, in which the regularity and symmetry of art are united with the wild grandeur and magnificence of nature. Many of the columns in the ranges at Fairhead are one hundred and fifty feet in height, and five feet in breadth. At the base along the shore is a wild waste of rocky fragments, which have fallen from the cliffs. Immense masses that have withstood the force of the shock lie in groups, resembling the ruins of enormous castles. At the Giant's Causeway the columns rarely exceed one foot in breadth, and thirty feet in height: they are sharply defined, and the columns are divided into smaller blocks, or prisms of one foot or more in length, which fit neatly into each other, like a ball and socket. The basalt is close grained, but the upper joint is cellular. The columns are most frequently formed with five or six sides; but some have seven or eight, and others not more than three. Beds of basalt that are not columnar, in some situations lie over and also under the columns. The basalt in these beds is cellular, and contains zeolites in its cavities. The columns at Fairhead are not articulated like those at the

Giant's Causeway; but the blocks, which are of great length in each column, lie flat on each other. Basalt appears to extend on the coast and inland about forty miles in length, and twenty in breadth.

The basaltic columns of the Island of Staffa are too well known to require a description; but, according to Dr. MacCullock, the columns which form the lofty promontory called the Scuir of Egg, another of the Hebrides, exceed in grandeur and picturesque effect those of Staffa: they are formed of black pitch-stone, containing crystals of glossy felspar. "The promontory rests on a bed of compact gray lime-stone, approaching to a stone marle. This bed, which is three or four feet thick, rests on a still lower bed of hard reddish stone. Masses of bituminized wood, penetrated with carbonate of lime, are found in the marle stratum not at all flattened. Portions of trunks of trees, retaining their original shape, but petrified (silicified), are found in the same stratum; the rifts are filled with chalcedony, approaching in aspect to semi-opal. The columns on this island are both perpendicular and inclined, and some of them are bent or curved."

In various other situations, as in Auvergne and the vicinity of Etna, the columns are also singularly curved, and are supposed by many geologists to have taken this form before cooling, or when they have been subsequently softened by subterranean fire.

Columns of porphyritic green-stone lie in heaps, and are thickly scattered over the northern side of Cader Idris, a mountain in Merionethshire: they are principally pentagonal and hexagonal, and vary in length from one foot to twelve. On this mountain is a cavity exactly resembling a volcanic crater.

We are not to be surprised that appearances like those presented by basaltic rocks should excite the attention and divide the opinions of geologists respecting their cause. The experiments of Sir James Hall and Mr. G. Watt, already alluded to, with the concurrent evidence of almost every one who has visited volcanic countries, strongly favour the opinion that basaltic rocks have been formed by subterranean or submarine fires. Ferrara has recently published a physical and mineralogical description of the burning fields of Sicily and the adjacent islands. His constant residence in a volcanic and basaltic country afforded better opportunities of observation than travellers possess, and he is decidedly of opinion that those who deny the volcanic or igneous origin of the basaltic columns in Sicily can never have seen them.

I am inclined to think that the part of Dr. Hutton's theory which relates to the igneous origin of basaltic rocks is as well established as the nature of the subject will admit of; other parts of the system are much less satisfactory. Mr. Werner, and most if not all of his disciples who deny the igneous origin of basalt, have never visited active volcanoes, and seem disposed to close their eyes upon their existence. Dr. Thomson, one of the most intelligent followers of Werner, in the excellent compendium of mineralogy which occupies four hundred pages in the fourth volume of his Chemistry, has dismissed volcanic products in eighteen lines. It is always desirable, but perhaps not always easy, to keep the description of facts distinct from the language of theory. With this limitation theories have their use, not only as they assist the memory in connecting insulated facts, but also as they induce us to examine nature, in order to prove the truth or fallacy of the system which we may be inclined to form or adopt. Theories are also better understood as they are brought to bear upon facts; on which account the introduction of the Neptunian and Plutonian theories has been omitted until the subject appeared to require it.

Whatever opinion we may form of the geological speculations of Werner, who has supported the former theory, it will not detract from his merit as an eminent mineralogist. By persevering industry, he has collected more facts in this department of science than any of his predecessors; it is much to be regretted that he has not extended his observations to districts which are the seat of active volcanoes. Having formed his system in countries remote from their immediate operation, he seems desirous of excluding them from nature, and is obliged to invent the most fanciful contrivances to supersede the agency of subterranean fire.

According to the theory of Werner, all the superficial parts of the globe were once in a state of aqueous solution, from which the materials were at first separated by chemical deposition in a crystalline state, and formed a thick mass of granite round the globe. Upon granite the primary rocks were successively deposited, forming layers over each other like the coats of an onion. Over these again were laid the transition rocks, and next the earthy stratified rocks. Each of these layers is supposed to encircle the globe, or to be an universal formation. While this process was going on, the waters were gradually retiring and became turbid: hence the materials which they deposited to form the upper strata were more earthy than those of the primary rocks; they were also intermixt with fragments of the rocks previously formed. According to this system, mountains and valleys were caused by the original inequality of the nucleus of the earth. So far the parts of Werner's theory are consistent, and we have a world ready made in which every thing might be supposed to remain quiet; but—*non sic Fata sinunt;*—Neptune, ashamed of his late retreat, and indignant at his confinement in such narrow limits, calls the infernal deities to his assistance, and rising in his might once more takes possession of the globe. He covers it with the depurgations of his turbid waves; but again he is compelled slowly and reluctantly to retire from the field, leaving behind him the basaltic rocks, the monuments of his triumph and his shame. Such is in substance the theory of Werner respecting the origin of all the superincumbent rocks of basalt and trap. They are also, according to this theory, universal formations. It is scarcely possible for the human mind to invent a system more repugnant to existing facts. Were basaltic rocks deposited from a solution which covered the globe after the formation of secondary strata, as Werner supposes, every part of the dry land and every valley must have been incrusted or filled with basalt; it would be the prevailing rock of every district. On the contrary, basalt exists only in detached masses in particular situations, nor do fragments of basalt occur in any quantity which can warrant the belief that it was ever formed universally over the globe. Nothing but the obscure language in which this doctrine has been advanced has prevented its absurdity from being instantly perceived and acknowledged*. Against the other part of Werner's theory, the universal formation of the primary, transition, and secondary conformable rocks, I think the only objection which can be offered is, that it appears to be in opposition to the universal evidence of facts; for there is not, perhaps, a country in the world, except that in which Werner formed his arrangement, where his entire series of universal rock-formations succeed each other. Many of the orders in each class are missing, and others supply their place in every district that has yet been examined. Now by what figure of speech that formation can be denominated universal which occurs only in one place, I leave the supporters of Werner to discover. It is not a little remarkable that the two instances which Professor Jamieson has given of the order of rock-formations, to prove the universality of their extent, are in opposition to his own system. The one is from the Hartz in Hanover, the other from the mine district of water beneath the melted mass: this water would be converted into elastic vapour, or steam, which would endeavour to expand; but where the superincumbent pressure of the ocean, or the tenacity of the lava, prevented its escape, it would be compressed, and form cavities, or air bubbles, at the bottom of the melted mass. In other instances, where the fluidity of the lava permitted the steam from below to escape through it, the mass would be compact, and form solid basalt, or green-stone. It might sometimes happen that water would be inclosed in the cavities of the mass, which is found to be the case in some basalt rocks.

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* By what cause the retiring and rising of the ocean were effected, this theory does not explain; nor would explanation be necessary, could the aqueous origin of basalt be established.

Thus, according to the different circumstances of pressure from the depth of the ocean, and the tenacity of the melted mass, porous or vesicular lava, or compact basalt, might be formed from the same eruption; or the mass might be porous below and compact above. When a volcano first breaks out on land, the surface of the earth opens for a considerable space, which at length is choked up with lava and stones, and the eruption is confined to one place, where it forms a cone or mountain. Through such extended fissures, the melted matter was poured out of submarine volcanoes, and spread in every direction over the bottom of the sea, to a limited extent: successive eruptions of a similar kind formed different beds over each other. If a considerable interval of time elapsed between these operations, loose materials with water-worn fragments might be collected upon the lower lava, and constitute a bed of tufa, which would separate it from the upper.

If ages passed away between the periods of two submarine eruptions, polypi and shell-fish might deposit their remains, and form a bed of lime-stone upon the first lava, which would be buried under that of the second eruption. In this manner I conceive the beds of amygdaloid and lime-stone were formed, which constitute the mountains in the mining districts in Derbyshire: that they were formed under the sea, cannot be disputed*. The agency of submarine volcanoes is now admitted: and if the ocean once covered the globe, as Werner supposes, all the volcanoes then existing were submarine.

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* The rapid formation of immense submarine rocks by polypi, in the South Sea, has been recently described by Captain Flinders, and is truly astonishing. *Voyage to Terra Australis.*

For the formation of basaltic columns, or regular prismatic forms, it appears requisite that the mass should cool slowly: and it is probable that most regular basaltic columns have been enveloped with an incrustration of uncrystallized basalt, which defended the internal mass from agitation, and permitted the crystalline arrangement of the particles to take place. Numerous instances might be cited of basaltic hills, in which the interior parts are columnar, and the outer part a confused indeterminate mass. In some instances the lava from submarine volcanoes has cooled suddenly, and formed beds of compact or porous basalt.

The following circumstances related by Colonel Imrie leave no doubt respecting the igneous origin of some columnar basaltic rocks. Felicuda, one of the most western of the Lipari or Eolean Islands, is from eight to nine miles in circumference and entirely formed of lava and other volcanic productions. From a conical crater in the centre of the island, Colonel Imrie says he could trace a stream of lava till it fell over a perpendicular rock, not less than sixty feet high, into the sea. "The lava here, even after it had passed over the verge of this precipitous declivity, still retained for a short distance a considerable degree of smoothness, but which was soon broken by narrow longitudinal furrows, appearing upon its surface. These lines at first only slightly marked their directions, but as they descended they became deeper and deeper until their interstices began to assume an approach towards form, and near to the water these forms were perfectly columnar." Upon some other parts of the shores of this island he observed in the currents of lava, these forms arrested in various stages towards a complete columnar shape*.

If basaltic rocks were once in a state of fusion, a passage must exist somewhere in their vicinity through which the basalt was ejected; though this passage may be concealed by the surrounding rock. A remarkable instance of this kind may be observed at the Titterstone Clee Hill in Shropshire. I believe it has not been previously noticed. I visited this hill in the autumn of 1811, to observe what geological relation it might have with the east side of Radnorshire, being the nearest coal district to that part of the county.

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* The same intelligent traveller has also related an instance of the columnar structure, in a mass of indurated clay or mud, formed at the bottom of a lake, now become dry, in the vicinity of antient Carthage. This is perhaps analogous to what takes place in the drying of starch.—*Transactions of the Wernerian Society.*

This is the highest mountain in Shropshire; its summit is covered with basalt, provincially called Jew-stone: detached blocks of basalt are scattered over its sides. A mass of basalt from fifty to sixty yards in thickness, consisting of blocks, also lies concealed under the surface. Round the hill are several small coal fields, in which the strata are arranged in basin-shaped concavities, dipping towards a centre, and appearing at the surface on many parts of the hill where it is not covered by basalt. The existence of this basalt in such an elevated situation, separated from any stone of a similar kind, excited my surprise; but I found on further examination, that a vast fissure or dyke, more than one hundred yards wide, filled with the same basalt, intersected the hill, cutting through the coal fields. It rises from an unknown depth, and appears to have forced a part of the coal to the surface. Where the basalt comes in contact with coal, it has injured its quality, and reduced it to a sooty state. Some idea of the position of the coal fields and the basalt may be formed by referring to plate III. fig. 2, where D represents the dyke of basalt intersecting the coal strata *ccc*, and *bbb* blocks of basalt*. There can scarcely be a doubt that this basalt was once in a state of fusion, and forced a passage for its eruption where the present basaltic dyke rises through the coal strata.

Mr. Bailey, in his Survey of the County of Durham, gives a description of a dyke of whin-stone or basalt, which intersects the coal fields in a part of that county, extending from Cockfield fell, by Bolam, to Ayton in Cleveland: it casts down the strata on one side twelve yards: it is about seventeen yards in breadth. Where it comes in contact with the seams of coal, the substance of the coal for several feet is converted into soot. At a greater distance from the basalt the coal is reduced to a coak or cinder, which burns without smoke, and with a clear and durable heat. At the distance of fifty feet from the dyke the coal is found in its natural unaltered state. It is particularly remarkable that the roof immediately over the coal is lined with bright crystals of sulphur, which were probably sublimed during the eruption of the melted basalt*. In the facts described by Mr. Bailey we recognise every circumstance which might be expected from the agency of subterranean fire, but which it would be extremely difficult to reconcile with the aqueous formation of basalt.

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* The fig. 2, plate III. may serve to convey a general idea of the position of the basalt dyke. A more correct representation was taken at the place; it was given to a gentleman, since deceased, or would have been inserted in this volume.

Having had an opportunity of examining this basaltic dyke, since the first edition of this work was published, it will be more particularly described in the subsequent chapters; it passes through the Cleveland hills eastward, and through the county of Durham on the west, where it expands, and is supposed to be the same which forms the basaltic rocks and columns on the banks of the river Tees in that country. The stone is of a dark or blackish brown colour, which is soon covered with an ocherous incrustation by exposure to the atmosphere; it is fine grained and nearly compact, some crystals of hornblende are dispersed in it. It is extremely hard, and is quarried in various parts of its course for the purpose of mending the roads. It rises to the surface along an extent of sixty or seventy miles.

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* In almost every kind of pit coal there is a quantity of pyrites or sulphur combined with iron, by miners called brass lumps, from their resemblance to brass; this sulphur is separated and sublimed, or driven off by heat.

The basaltic columns in the upper part of Teesdale are of considerable magnitude; at Holwick they are from thirty to forty feet in length. Caldron Snout, a water-fall on the river above that called Tees-force, is surrounded by basaltic columns. The basalt (green-stone) at Tees-force is composed of white felspar and hornblende, it rests on black lime-stone containing organic remains.

Among basaltic rocks may be enumerated gray-stone, which differs little from green-stone except in its colour; it consists of white felspar and black hornblende; it passes into basalt.

Clink-stone and clink-stone porphyry, so called on account of the metallic sound which they yield when struck, are in their constituent parts nearly allied to basalt, and like it contain a quantity of soda in their composition. They appear to be an intermixture of compact felspar or clay-stone with basalt. Clay-stone may be considered as compact felspar, but in a more earthy state.

Basaltic mountains are frequently isolated and conical, but have sometimes flat tabular summits.

" In the Canary Islands, in the mountains of Auvergne, in Bohemia, in Mexico, and on the banks of the Ganges, the formation of trap and basalt is indicated by a symmetrical arrangement of the mountains by truncated cones, sometimes isolated, sometimes grouped and by elevated plains, both extremities of which are crowned by a conical ring. These rounded tops, in the form of domes, or bells, of porphyry or basalt, are supposed by some philosophers to have been heated in their original situations below the surface, and forced up in a softened state, without having ever flowed as real stony lavas*."

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* Humboldt's Researches,

When basalt is decomposed, and intermixt with fragments of rock cemented by loose clay, it is called basaltic tufa. Some basalts decompose rapidly, and form productive soils. I have seen a mound formed of basalt that had been got out of a mine by blasting with gunpowder, and which a respectable miner informed me was once extremely hard and resisted the point of the pick; but by exposure to the air for thirty years it was converted into a rich mould, and covered with a luxuriant crop of vegetables. Some very dark-coloured compact basalts and lavas appear to resist the decomposing effects of the atmosphere more powerfully than any stone. The asperities and protuberances on the basaltic rocks in Auvergne are described by D'Aubuisson as preserving all the appearances of the recent action of volcanic fire, and are so fresh, that he says it seems as if the melted matter were still trickling from them, 'ils semblent degoùtter encore.' The antiquity of these rocks is lost in the darkness of past ages, as the volcanoes of Auvergne were anterior to historic records, and probably to the present condition of the globe.

CHAPTER VII.

ON SECONDARY STRATA AND ROCK-SALT FORMATIONS.

Strata of Secondary Rocks of limited extent.—Succession of Organic Remains marking the changes which have taken place on the surface of the globe.—Rock Salt Formations: Opinions respecting their Origin.—Valley of Rock-Salt at Cardona in Spain, Rock-Salt of Cheshire and various parts of the world.—On the Accumulation of Salt in the Ocean.

SECONDARY stratified rocks are widely extended over the globe. They form gentle swelling hills, which seldom rise to a great elevation. They contain few metallic ores; but are the repositories of the most useful treasures of the mineral kingdom, coal, ironstone, and rock-salt. Districts composed of secondary rocks constitute the habitable parts of the world. Alpine mountains are covered with eternal snow, or exposed to the fury of the elements; their declivities are too steep to admit the accumulation of soil, and it is only in the sheltered valleys by which they are intersected, that man and the animals he has domesticated can find the means of support. On the contrary, countries formed of secondary rocks are generally capable of cultivation over the whole surface.

Secondary rocks include

1 Siliceous sand-stone or grit-stone.
2 Argillaceous sand-stone and shale*.
3 Earthy lime-stone.
4 Calcareous sand-stone.
5 Chalk.

They contain beds of

Gypsum.
Rock-salt.
Iron-stone.
Coal.
Trap or basalt.

In what I am about to state, it will be perceived that the arrangement and succession of the rocks of this class vary in different countries. Where they exist in an uninterrupted series, descending from mountains of granite, slate, and metalliferous lime-stone, to the sea shore, they frequently occur in the following order:—First, coarse siliceous sand-stone and shale covering metalliferous lime-stone; next, argillaceous sand-stone and shale, containing iron-stone and coal, intermixt with finer-grained siliceous sand-stone; after these, earthy lime-stone and different kinds of sand-stone; and lastly, chalk, which was considered as the most recent formation of lime, until the late discovery of calcareous strata over it considered by some geologists as a fresh-water formation.

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* Shale is a more distinct term to designate this substance than slate-clay, which may be confounded with clay-slate or argillaceous schist. Shale is principally formed of clay more or less indurated, approaching to the quality of slate. It divides into plates or laminæ: hence in the northern counties it is called plate.

Most of the rocks called secondary are generally distinctly stratified, and some of them contain water-worn fragments and pebbles of other rocks. When they are principally composed of the debris of other rocks, they have been sometimes denominated *tertiary*. Geologists have generally admitted that secondary rocks were arranged by the agency of water. It has been supposed that they owe the regularity of their stratification to the action of the tides; but it is difficult to conceive that this has been the case with coal. The German geologists assert that secondary rocks as well as primary constitute what they call universal formations, and are to be met with in every country, lying over each other in one determinate order; but if this were true, we should not perceive that great diversity which every where prevails.

In no part of England with which I am acquainted do the secondary strata agree with the arrangements of Werner. One cause of this difference results from a fact admitted by Werner and his disciples, who are agreed that many of the secondary strata are principally formed from the debris or fragments of pre-existing rocks. If such be their origin, it is to be expected that they will vary according to the nature of the mountains in their vicinity at the time of their formation.

In some situations elevated ranges of mountains have been rapidly decomposed; in others they have resisted the action of the elements: hence we may expect that different districts will have a great diversity of secondary strata, and such is found to be the fact. Though I am far from admitting that the greater part of the strata called secondary are mechanical depositions (see chapters X and XVI), some of them are evidently so, or are much intermixt with mechanical deposits.

Many lime-stone mountains are principally formed of one species of marine shells. In some of the strata they are distinctly perceptible, and compose nearly the whole mass; but we cannot suppose that beds of one particular kind of shell-fish have at any time encircled the whole globe. Lime-stone must therefore exist partially in different countries, and be entirely wanting in many situations:—this is confirmed by numerous observations. And it not only holds true with respect to lime-stone composed principally of organic remains, but of other lime-stones in which no such remains occur. But the principal argument against the universal formation of secondary strata rests on the fact that there is no stratum which has, or can be, traced over any very considerable portion of the globe; and even where a stratum has been traced to the distance of several miles, it frequently varies so much in its thickness and contents as to render its identity doubtful.

The rocks of the second class, called transition rocks, have been before described as containing remains of zoophytes, and marine animals, which no longer exist on the globe.

In the strata which cover them, these marine remains cease to appear; but they generally abound with impressions of vegetables, and contain much carbonaceous and bituminous matter, and frequently alternate with regular beds of coal. The striking change in the nature of these organic remains, from marine animals to vegetables, marks that a great revolution had taken place in the condition of our present continents, after the formation of the mountain lime-stone, and before the deposition of the coal strata. To whatever causes we are to attribute this change, it has also been attended with another effect not less remarkable; after this period the formation of metallic veins appears to have almost entirely ceased, for they very rarely shoot up into the secondary strata which alternate with coal.

We have a remarkable instance of this change from animal to vegetable remains in the prevailing rocks of some of the northern counties. The metalliferous mountains of lime-stone which extend through the Peak of Derbyshire, and through Craven in Yorkshire, abound exclusively with the organic remains of marine animals. They are covered on the eastern side by two thick beds which contain carbonaceous and bituminous matter and vegetable impressions. The lowest is from one hundred and fifty to one hundred and seventy yards in thickness. It is called by Mr. Farey* lime-stone shale, because it occurs over lime-stone. It is composed principally of thin strata of shale and sand-stone. Where it is exposed to the air it is of a dark reddish brown colour; over this lies a bed of coarse grained siliceous sand-stone, not less than one hundred and thirty yards in thickness. It has been called mill-stone grit by Mr. Whitehurst and the miners in the north of England, from being used for the purposes of mill-stones. These two beds separate the metalliferous lime-stone from the coal strata in that part of England; for, though thin seams of coal sometimes are met with, they do not contain any of sufficient thickness to be worked, except, indeed, what sometimes occur in detached basins or hollows formed in these beds, provincially called swilleys. Such coal basins are also found in the lowest red sand-stone on the western side of England.

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* Farey's Derbyshire.

gland. The occurrence of these detached series of strata in basin-shaped concavities affords reason to believe that these hollows were once lakes, at a period when the present continents were emerging from the ocean. That lakes both of salt and fresh water, of vast extent, have once covered a considerable part of the dry land, is rendered extremely probable by a variety of existing monuments. Such must in fact have been the case before rivers and currents had opened a passage from the higher valleys to the lower plains. At this æra most of the great formations of rock-salt appear to have commenced, prior to the formation of the coal strata, for they occur in beds whose geological position is subjacent to the regular coal formations.

The lowest red sand rock, described in the fourth chapter, has been considered as the peculiar repository of rock-salt; but it may more properly be said to be surrounded by this rock lying in basins or hollows, covered by beds of indurated clay-gypsum and marle, but not by the red sand-rock itself.

The occasional occurrence of brine-springs in the lower series of coal strata proves the existence of rock-salt below. These strata generally lie in basin-shaped concavities, and have probably been formed in valleys which were once lakes. Were we well acquainted with the peculiarities of many of the principal rock-salt formations, we should perhaps discover that their original formation had also been in hollows or lakes. The rock-salt formation at Cardona, in the province of Catalonia, affords an illustration of this mode of formation. From a drawing and description by the Count Alexander La Borde, given in his magnificent work (Voyages Pittoresques dans l'Espagne), and from personal communication with that intelligent traveller, I am enabled to give an account of this remarkable valley, hitherto so imperfectly known in this country.

"The salt district of Cardona comprehends the hill on which the town is situated, and the environs of more than a league in circumference. The surface is almost every where covered with vegetable soil to the depth of six inches or more, which renders it productive. The place where the rock-salt is procured is a valley forming an oval, about one mile and a half in length, and half a mile in breadth from east to west, extending from the Castle of Cardona to the promontory of red salt at the other end. The last is the most considerable of the salt rocks, and has not yet been worked; it is six hundred and sixty-three feet in height, and twelve hundred and twenty feet in breadth at its base. This valley is also traversed by a chain of hills of rock-salt: besides these, there are other rocks of salt at the feet of the fortress, and upon the declivity of the mountain which stretches to the fountain called Cancunillo. The mountain of red salt is so called because that colour predominates; but the colours vary with the altitude of the sun, and the greater or less quantity of rain. At the foot of this mountain a spring of water issues, which comes through a fissure we perceive on the summit. The rivulet runs all along the valley from the east, but passes under ground in part of its course, particularly under the hill where the rock-salt is mined; it rises again to the surface at a little distance; and, after running along the plain, discharges itself into the river Cardona. This brook in rainy seasons swells the waters of the river, which then become salt, and destroy the fish. But at three leagues lower the water has no perceptible taste of salt. All these salt-mountains are intersected by crevices and chasms, and have also spacious grottoes, where are found stalactites of salt shaped like bunches of grapes, and of various colours. "Nothing can compare with the magnificence of the spectacle which the mountain of Cardona exhibits at sunrise. Besides the beautiful forms which it presents, it appears to rise above the river like a mountain of precious gems, displaying the various colours produced by the refraction of the solar rays through a prism. Thus the imagination of the Arabian poets pictured their palaces of diamonds constructed by fairies and genii in the solitudes of Asia:" (the Count adds) "Aux environs de Cardona, où l'on peut contempler de loin le beau spectacle de la montagne, qui se developpe sous le firmament azur de l'Espagne, on croit voir un arc en ciel tombé sur la terre, où le Mont Olympe, lorsque Jupiter et tous les dieux descendent y tenir leur cour. Le fleuve Cardona, qui coule au milieu des oliviers et des lauriers roses, donne l'idée de Penée parée des arbres de Minerve et d'Apollon."

Travellers had described the rock-salt of Cardona as a detached mountain, which gave a very erroneous idea of the place. Though the salt here is of various colours, the most prevailing are red and dark green, *verd foncé*.

The annexed plate will give a more distinct idea of this formation of salt than the most elaborate description alone can possibly convey. The Count obligingly gave instructions respecting the colouring.

It is a bird's eye view, commanding the elevated plain in which the valley is excavated as well as the valley itself, the lofty cliffs of rock-salt on its sides, the chain of hills of rock-salt which range along it, and the promontory of red salt at the further extremity, with the river Cardona and the mountain of salt on which the town is situated, at the nearer end of the valley. The second rock in the valley is that which is at present worked for salt, and under this the rivulet passes in a subterranean channel. The basis of the whole plain is composed of rock-salt, but the surface is covered with soil, and planted with vineyards. It was probably once the bottom of a salt lake, of which the distant mountains formed part of the boundary.

There is an extensive formation of rock-salt, stretching on each side of the Carpathian mountains for six hundred miles, from Welielska in Poland towards the north, to Rimnie in Moldavia on the south. It has indeed been observed that rock-salt and brine-springs most generally occur near the feet of extensive mountain ranges, which adds probability to the opinion that these ranges were once the boundaries of extensive salt lakes.

The principal salt formation of England extends at some little distance from the western side of the hills which divide the rivers that flow into the eastern and western sea.

The rock-salt of Cheshire cannot properly be said to lie in or under the red sand rock before described, but is surrounded by it, and probably rests upon it; but as the lowest bed of salt has not been sunk through, this cannot be yet ascertained. The upper bed of rock-salt in that county is about forty-two yards below the surface: it is twenty-six yards thick, and is separated from the lower bed of salt by a stratum of argillaceous stone ten yards thick. The lower salt has been sunk into forty yards. The upper bed was discovered about a hundred and forty years since in searching for coal. Rock-salt at Northwich extends in a direction from N. E. to S. W. one mile and a half: its further extent in this direction has not been ascertained; its breadth is about fourteen hundred yards. In another part of Cheshire three beds of rock-salt have been found. The uppermost is four feet, the second twelve feet, and the lower has been sunk into twenty-five yards, but is not cut through. Besides the beds of rock-salt, numerous brine springs, containing more than 25 per cent. of salt, rise in that county. The transparent specimens of rock-salt are nearly free from foreign impurities, and contain scarcely any water of crystallization. In sea water a large portion of muriate and sulphate of magnesia is found, which gives it that bitter nauseous taste distinct from its saltness. This difference in the composition of sea-water and of rock-salt might seem to indicate that rock-salt was not, as some suppose, produced by the evaporation of sea-water. But if it were formed in detached lakes, it is possible that the waters of these lakes did not contain precisely the same salts in solution as those of the sea. We know that the waters of some of the salt lakes existing at present differ in their contents from sea-water. If, however, the evaporation were very slow, the salt of the ocean would separate from all its impurities by crystallization, and the latter, being more deliquescent, might be washed away.

It may deserve notice, that few, if any, remains of marine or other organized bodies are found in the beds accompanying the rock-salt of Cheshire. In the Polish salt-mines bivalve shells and the claws of crabs are met with in the upper strata of marle; and vegetable impressions in the bed covering the lower salt, at the depth of two hundred and twenty-five yards from the surface.

The salt formation at Droitwich in Worcestershire appears to be surrounded by the same kind of rock, and covered with similar beds of gypsum and marle to that of Cheshire. Here the rock-salt, though its existence has been proved by boring, is no where worked. The salt is procured by evaporating the water, which is nearly saturated with it.

Salt springs occur in some of the coal strata of Northumberland and Durham, particularly at Long Benton, in the former county, where the proprietors have the exclusive privilege of extracting soda from it without paying the regular duty. A spring of brine rises in the river Wear, in the county of Durham.

Brine springs, containing from 5 to 6 per cent. of salt, rise in the coal mines near Ashby de la Zouch in Leicestershire, at the depth of two hundred and twenty-five yards under the surface. A weaker brine also rises in the upper strata: it springs through fissures in the coal, attended with a hissing noise occasioned by the emission of hydrogen gas.

I examined these mines belonging to the Earl of Moira in the summer of 1812: they are situated at Ashby Wolds, in the very centre of England*; and what may appear remarkable in this situation, they are worked one hundred and forty yards below the level of the sea, which is ascertained from the levels of the canal that passes by the pits. Had this circumstance been known before the attention of geologists was directed to the structure of the earth's surface, it would have been inferred that brine springs so far below the level of the sea had their source from the waters of the ocean percolating through fissures in the earth.

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* From some experiments I made to determine the strength and purity of this brine, and the quantity supplied by the brine from two mines per day, I ascertained that nearly eight hundred tons of salt are thrown away annually, which might be evaporated at a very trifling expense, as the small coal at hand, which would answer for the purpose, is made no use of. But here, as in numerous other instances, the excise laws present an insuperable bar to the profitable application of our own natural riches. For the

Rock-salt occurs sometimes in very elevated situations, as in Peru, where it is found at

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the duty bears such an overwhelming proportion to the amount, and requires so much capital, that eight hundred tons is too small a quantity to support an establishment for the manufacture of salt. Under a system so vexatious as that of the excise, with its train of spies and informers, no improvement dare be attempted in the manufacture of soda and salts prepared chemically; the excise is in fact a prohibition to the manufacture of soda, except for one purpose only, the making of glass. Thus we are compelled to import from other countries, at a heavy expense, what we throw away at home. No blame, however, can possibly attach to our present or late ministers for the existence of a system long since established. Dr. Johnson, in his Dictionary, half a century ago, defined the excise to be "a hateful tax on commodities, not adjudged by the common judges of property."

at the height of nine thousand feet above the level of the sea, accompanied with sand-stone and gypsum. It may however deserve inquiry, whether rock-salt ever exists but where there is still higher ground in its vicinity. The salt in the soil near the Caspian sea and the sea of Aral may probably have been left when those seas were contracting their bounds.

In the lofty deserts of Caramania in Asia, according to Chardin, rock-salt is so abundant, and the atmosphere so dry, that the inhabitants use it as stone for building their houses. This mineral is also found on the whole elevated table land of Great Tartary, Thibet, and Indostan. Extensive plains in Persia are covered with a saline efflorescence; and according to the account of travellers, the island of Ormus, in the Persian Gulf, is one large mass of rock-salt.

On the banks of the river Missouri in North America, a chain of mountains is said to extend eighty miles in length and forty-five in breadth, and of considerable height, consisting of pure rock-salt, barely covered with earth, but without any tree or shrub. It exists also in the state of Kentucky. The repositories of this mineral are there called

Licks,

and sodium. It has so little water of crystallization, that it scarcely decrepitates when thrown on burning coals, in which it differs from salt prepared artificially by evaporation. Specimens of rock-salt sent me from the Polish mines are less disposed to deliquesce than those from Cheshire. The deep red colour very common to rock-salt is derived from the oxyd of iron. Clay or marle commonly accompany rock-salt; it frequently lies imbedded in clay in detached masses; the clay is often much impregnated with salt, which is extracted from it by solution in water. The almost constant occurrence of sulphat of lime (gypsum) with rock-salt is also a fact of considerable interest. It is curious to observe the two most powerful acids, the sulphuric and muriatic, so nearly associated in the same place. This fact, in a more advanced state of science, may elucidate the chemical changes which have effected the formation of these minerals.

The most natural hypothesis respecting the formation of rock-salt, at least in some situations, is that before stated, which attributes it to the gradual evaporation of lakes and pools of salt water that remained when the ocean retired from our present continents. By slow evaporation this mineral, which is nearly pure, would be separated from the sulphat of magnesia and the sulphat of soda, that exist in sea water. These salts being also more deliquescent, might be washed away before the beds were covered with other strata. Whether beds of rock-salt have generally suffered the action of subterranean fire, by which they were rendered confluent and consolidated, as some philosophers have supposed, may be doubted. Pressure and time are perhaps adequate to the production of many phænomena in the mineral kingdom, which have been attributed to other causes; for, from various circumstances which will be noticed, it appears that the particles of solid bodies are not in a quiescent state, but are capable of assuming a crystalline arrangement at a comparatively low degree of temperature. Had subterranean fire in all instances been the cause of the evaporation which produced sea-salt, its composition would scarcely have been so pure as it is at present found, and the action of this fire on the upper strata must have produced some effects on the intermediate beds of clay, &c. It may excite surprise that a mineral so soluble as rock-salt should remain for ages exposed to the influence of the atmosphere; but most of the countries in which this mineral is found in elevated situations, are those in which rain very rarely falls, and it is generally protected by a thin covering of clay or marle. It must however be gradually, though insensibly, diminishing by atmospheric moisture and by subterranean waters, which carry off a portion of it to the ocean. From various experiments it appears, that the water taken from considerable depths in the sea contains more salt than that near the surface; it is also somewhat salter after stormy weather than before; which can only be explained by admitting that the lower waters are at such times more intermixed with the upper. These facts may perhaps throw some light on the formation of rock-salt. If pressure or any other cause be sufficient to suspend the power of chemical affinity, which would diffuse the salt equally through the whole mass of water, it may at still greater depths occasion the deposition of the saline contents at a much lower state of concentration than would be required to separate it at the surface. Late discoveries have made us acquainted with a power which can not only suspend but reverse the common laws of chemical affinity. When we see the effects of the voltaic energy produced by the superposition of small plates of various substances*, can we believe that the atmosphere, the ocean, and the earth cover each other without producing effects commensurate to the immense surfaces which are in contact? All the rivers which flow into the sea carry with them a quantity of various salts in solution, whilst the water raised by evaporation, and returned to the earth, is nearly pure. We must therefore admit that the ocean is becoming salter, or that some natural process is constantly depositing a portion of its saline contents, by which its waters are preserved in the same state of strength and purity through succeeding ages.

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* I refer to the very curious column of M. De Luc, in which the electric power is in a state of incessant activity without any apparent diminution of strength, or decomposition of the metallic surfaces.

CHAP-

CHAPTER VIII.

ON SECONDARY STRATA CONTAINING COAL AND IRON-STONE.

Repositories of Stratified Coal.—Brown Coal.—Black Coal.—Peculiarities of Coal Strata.—Dislocations or Faults, their Effects on the Water in Coal Mines.—Position and Geological Relations of Coal Strata.—Observations on the Modes of searching for Coal.—Iron-stone accompanying Coal.—Precautions necessary in the Establishment of Iron Furnaces.—Varieties of Coal.—Plumbago.—On the Origin and Formation of Coal.—On Aluminous Shale or Schistus in Coal Strata.

THE secondary strata which lie upon the metalliferous lime-stone, or on the red sandstone, are the proper repositories of coal and iron-stone; coal very rarely occurs with lime-stone, and is never found in the upper calcareous strata composed of roe-stone and chalk.

Coal is a substance too well known to require a particular description: it may be divided into brown and black coal. The former, sometimes called wood coal, is chiefly found in alluvial ground. It contains besides charcoal and bitumen, vegetable principles, and branches or trunks of trees partially decomposed, which mark the origin of this kind of coal.

Black coal is composed of charcoal, bitumen, and earthy matter. The latter forms the ashes which remain after combustion; these vary in proportion in different coals, from two to near twenty per cent. The proportion of bitumen varies from twenty to forty per cent. and the charcoal from forty to more than eighty per cent.

Mineralogists have enumerated many different kinds of black coal: several of these pass by gradation into each other in the same mine. The most important varieties in an œconomical view are the hard coal, like that of Staffordshire, and bituminous or caking coal, called in London sea coal.

Black or common coal forms regular strata which vary in thickness, from a few inches to several feet or even yards; they occur over each other, separated by beds of clay or stone. The series of strata existing in one situation is denominated a coal field.

Every district appears to have its peculiar series of strata unconnected with any other: hence, the series of stratified coal have been denominated independent coal formations.

The different strata which accompany coal consist of beds of clay, more or less indurated, which occasionally contain shells resembling those of fresh water muscles, loose stones called rubble, sand-stone of various qualities and degrees of hardness, argillaceous shale called coal shale coloured with bitumen and strata of iron-stone. Many of the strata abound in vegetable impressions of ferns, and of other plants which are either unknown genera or belong to tropical climates.

The different strata under a bed of coal are frequently similar to the strata over it, and the same series is again repeated under the lower beds of coal, and sometimes with a perfect similarity both in the succession and thickness of each. In some instances a single bed of stone of vast thickness separates two beds of coal. In other instances only a very thin stratum of shale or clay lies between coal beds. The succession of the coal strata in Northumberland is given from Westgarth Forster's section, plate 7. fig. 2.

Numerous beds or seams of coal occur

in one coal field, but very rarely more than three of these are worked. The thickness of coal seams or beds varies from a few inches to several yards; but each of these generally preserves the same thickness throughout its whole extent, when not broken by dislocations of the strata. Instances to the contrary sometimes occur, in which the same bed will be narrower or wider, and sometimes divided by a stratum of incombustible earthy matter in different parts of its course. Few beds of coal are worked at a great depth which are less than two feet in thickness. The stratum lying over a bed of coal is called the roof, and the stratum under it the floor. The facility of getting coal depends very much on the compactness of the stone which forms the roof, not only on account of the security from falling, but for keeping out the upper water and preserving the pit in a dry state. The great expense incurred in supporting the roof when it is loose, frequently prevents a valuable bed of coal from being worked, or absorbs all the profit. In some situations the roof is indurated clay, impregnated with bitumen and pyrites. When this falls down, and is intermixt with water and small coal at the bottom, it takes fire spontaneously; on which account the miners close up the space with clay where the coal has been worked, to prevent the access of air to the combustible matter. This kind of clay is called '*tow*,' it is common in the Ashby de la Zouch coal field, and in Staffordshire.—The floor or stratum on which the coal lies, consists of clay in various degrees of induration, and is almost always of that kind which will resist the action of fire, called fire clay, suited for furnace bricks and crucibles. (See Mr. Farey's Derbyshire 179.)

Coal strata are frequently bent in concavities, resembling that of a trough or basin, dipping down on one side of the field and rising on the other. In plate II, fig. 2. the section of a coal field is represented, in which the coal strata *C C D D* are inclined in this manner, but partially dislocated by a fracture or fault at *f*. The extremities of the lowest stratum *C C* are several miles distant in some coal fields, in others not more than one.

In the great coal field in South Wales, the strata are arranged in this manner over an extent of one hundred miles. At the Clee

Hills in Shropshire the breadth of some of the coal fields is not a mile. At Ashby Wolds in Leicestershire, in the central part of the field at *e*, the main bed of coal is worked at the depth of two hundred and forty yards; but by the bending and rise of the strata, the same bed comes to the surface at *C*, about three miles distant. The depth of coal strata is very different in different situations, and, from the inclination or bending of the strata, differs much in the same district, as will be evident from what has been stated, and from an inspection of the last mentioned figure. Some coal fields extend in a waving form over a district.

On the eastern side of England, the strata generally decline, or in the miner's language dip to the south-east point: on the western side, the strata are more frequently thrown into different and opposite directions by faults or dykes; two fractures of this kind filled with basalt were described in the fifth chapter.

In some instances the coal strata are thrown down or raised on one side of a dyke more than one hundred and fifty yards, and the miner after penetrating through it (see plate II. fig. 3. *d.*) instead of finding the same coal again, meets with beds of stone or clay on the other side at *e*: hence he is frequently at a loss how to proceed in searching for the coal which is cut off; on which account such dykes are called *faults*. If the stratum of stone *e* be the same as any of the strata which were sunk through in making the pit or shaft *g g*, it proves that the bed of coal is thrown down on the side of the fault at *e*, and he can determine the exact distance between that stratum and the coal he is in search of. But if the stone is of a different kind to any which was above the coal *c c*, he may be certain that the strata are raised on that side; but to what distance can only be ascertained by trial, if the under strata of the coal bed *c c* have not been previously perforated. It frequently happens, however, that two or more strata of stone or shale at different depths are so similar in their quality and appearance that it is impossible to distinguish them: in such cases it is necessary to perforate the stratum to ascertain its thickness and examine the quality of the strata above or below it, by which its identity with any known stratum may generally be ascertained. The manner in which the strata are inclined towards the fault will also determine whether they are thrown up or down, provided they are not shattered where they come in contact with it; which is frequently the case*. Each bed of coal in a coal field has certain characters by which it may generally be known to be the same. Its thickness, and the quality of the roof and floor, with that of the upper and under strata, generally serve to identify it, though it may sink deeper in one place than another, and vary in distance from the surface five hundred feet.

The dykes or faults which intersect coal strata are generally impervious to water, and it not unfrequently happens, that where the strata decline to them they hold up the water and occasion springs at the surface, or keep the coal works on that side of the fault under water, when the coal works on the other side are dry. This will be better understood by referring to plate II. fig. 2. and 3, where the coal strata on the right hand of the faults decline or dip to them, and the water which passes through or between the strata will be stopped at the faults and held up, should any of the lower strata be also impervious, in which case the coal beds to the right of the fault will be under water, and those on the other side dry. Now should a perforation be incautiously made through the dyke, all the water will be thrown upon the works on the left that were before dry. Where the wall on each side of a fault belongs to different proprietors, a few strokes with a pickaxe may thus do incalculable mischief to those on the one side, and render great service to the other by laying their pits dry.

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* If the dyke make an acute angle with the upper surface of the strata, they are thrown up on that side; but if it make an obtuse angle, they are thrown down. See pl. II. fig. 2. In the plate to the first edition this figure was incorrectly given.

The deepest coal mines in England are those in Northumberland and in the county of Durham, some of which are worked nearly three hundred yards below the surface. The thickest bed of English coal of any considerable extent is the main coal in Staffordshire, which is thirty feet. The upper, lower, and middle parts of the bed differ in quality. Mr. Keir, who has written an interesting account of the mineralogy of the south of Staffordshire, says that thirteen different kinds of coal occur over each other in this bed; the uppermost, which is compact, serves as a roof in getting the under coal. At the Wood Mill-hill colliery in this county, the coal is said to be forty-five feet thick, and three beds of coal from three to four feet in thickness, have been found under it, since Mr. Keir's account was published. The first is only two yards under the thick coal. The main bed of coal in the Ashby de la Zouch coal field is thirteen feet thick; the upper and lower seams of this bed also vary in quality, and the top serves as the roof, being more compact than the stratum over the coal. Few beds of coal in other parts of England or in Wales exceed from six to nine feet in thickness; but a difference in the quality may generally be observed in the upper, lower, and middle parts of the same bed. A curious fact is stated by Mr. Keir respecting the main coal of Staffordshire:—in one situation the upper part of the bed separates from the lower, and rises to the surface, or crops out. It is at first divided by indurated clay called bind or clunch; but as the distance becomes wider, the intervening stone grows harder, and will strike fire with flint. Similar separations take place sometimes in the beds of coal in the mines of Northumberland and

Durham. The largest known bed of coal in the West Riding of Yorkshire is near Barnsley: it is ten feet thick, and is supposed to be formed by the meeting of two or more seams, which soon separate again. The miners have not been able to trace the same bed in situations where it might have been found had it preserved the same thickness in other parts of its course.

Coal strata, beside the more common dislocations by faults, present remarkable contortions which it would be difficult to explain, except by admitting a lateral force which has compressed them into a zig-zag form. To the same cause, or perhaps to a partial sinking of the earth, we may attribute the origin of what is called faulty ground, which frequently occurs in coal fields. In this no actual dyke appears to have been formed; but the beds of coal with all the accompanying strata are so broken and shattered, that no workings can be carried on till the miner has got through them into regular strata. These broken spaces or faulty grounds occasion much more difficulty to the miner than common faults or dykes, and are sometimes of great extent.

In some coal fields one part of a stratum is inclined, and the other part vertical. A curious fact of this kind may be seen in a small coal field near the town of Manchester*.

The position of coal strata in many coal fields may be represented by a series of fresh-water muscle shells, decreasing in size, laid within each other, but separated by a thin paste of clay. If one side of the shell be raised, it will represent the general rise of the strata in that direction; and if the whole series be dislocated by partial cracks, raising one part a little, and depressing the other, to represent faults in the coal, it will give a better idea of the coal field than any description can convey. We are here to suppose that each shell represents a stratum of coal, and the partitions of clay the earthy strata by which they are separated. The outer shell represents the lowest bed of coal, which may be many miles in extent. Now if a much larger shell be filled with sand, and the lowest shell be pressed into it, we may consider the large shell to represent lime-stone, and the sand grit-stone; we shall then have a model of the coal strata in many parts of England, and their situation over the metalliferous lime, with the beds of sand-stone by which they are separated from it.

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* I have given a short account of this coal field in the second volume of the Transactions of the Geological Society.

From the inclination or bending of coal strata, they always rise near to the surface in some parts of their course, and would be visible if not covered by soil or gravel. In the intersections formed by rivulets, or by accidental fractures on the sides of hills in a district, the nature of the strata may often be determined, and should be ascertained before any expense be incurred in boring or sinking for coal. When this is done, a proper station should be chosen; which requires great judgement: otherwise it is possible to bore or sink to great depths, and miss a bed of coal which exists very near the place: this will be evident from the inspection of the two stations, *a* and *b*, plate II. fig. 2: in the latter it would be impossible to meet with the bed of coal, *C*, because the search is made beyond the line where it rises to the surface, or, in the miner's language, crops out. At *a* coal would be found after sinking only a few yards. In most situations it is better to search for coal, as deep as can be done without expensive machinery, by sinking a well in preference to boring. By sinking, a decisive knowledge of the nature and thickness of the strata can be ascertained as far as you descend, which can only be imperfectly known by boring: for the latter mode is liable to great uncertainty of result, from bendings or slips of the strata. If, for instance, the borer be worked in the situation *a*, plate II. fig. 2. it will pass through a great depth of coal, which in reality may not be more than a few inches in thickness. Besides the uncertainty of the results, the grossest impositions are sometimes practised to answer interested purposes, and induce proprietors to continue the search where there is no reasonable probability of success. Where coal strata come to the surface, they are generally in a soft decomposed state, and intermixt with earthy matter. They frequently present no appearance of coal, but the soil may be observed of a darker colour. The real quality of the coal cannot be ascertained, until it is found below in its natural undecomposed state, lying between two regular

gular strata of stone, or indurated clay. In general it is observed that the same bed improves in quality, as it sinks deeper into the earth. Coal strata are generally split or divisible into rhomboidal blocks, by vertical joints, which range about E. S. E. and W. N. W.: these are called slines; the oblique shorter joints are called cutters.

From what will be stated in the subsequent chapters, it will appear that there is more than one third of England, in which all search for valuable coal is useless: the knowledge of a negative fact becomes important when it saves us from loss of time, expense, and disappointment.

Coal strata are frequently accompanied by thin strata of iron-stone. This stone has a dark brown or gray colour, and is about three times heavier than an equal bulk of water. Some kinds have a specific gravity of 3.6. Though modern mineralogists call this mineral, clay-iron-stone, after Werner, from its resemblance to argillaceous stones, on analysis it is found to contain but a very minute portion of alumine or pure clay, sometimes not more than two per cent. It is principally composed of iron combined with oxygen and water, and a small quantity of silex, and in some instances with calcareous earth. If it be of a good quality, it yields more than 30 per cent. of iron. In some of the beds of clay over coal detached nodules of iron-stone occur, which are also smelted for iron.

The vast extent and importance of our iron-works are well known, but their establishment is of recent date. Formerly our furnaces were on a diminutive scale, and wood or charcoal was the only fuel employed: but in the present cultivated state of the country, wood could not be procured in requisite quantity. The application of coal or coke to the smelting of iron is among the most useful of modern improvements: but it is only some kinds of coal that are proper for the purpose. Inattention to this circumstance has frequently led landed proprietors to great unprofitable expense. Finding ironstone and coal in abundance upon their estates, they have constructed furnaces and other works at a considerable cost, and have discovered too late that the coal, however suitable for domestic or other uses, was unfit to make iron of a marketable quality. To make good iron from the best iron-stone, it is necessary that the coal should be as free as possible from every substance with which sulphur is combined. It should possess the property of forming a hard coke or cinder; and if it have the quality of cementing or caking, it is the more valuable, as the small coal can be used for the purpose of coking, which is frequently wasted where it does not possess this quality.

Where beds of coal are covered with basalt, some geologists consider them as belonging to a distinct formation, which the Germans call the *flœtz trap formation.* There does not appear any sufficient reason for the distinction. Mr. Jameson has mentioned the islands of Mull, Iceland, and Sicily, as affording instances of this coal: he says it "occurs in great abundance in Iceland, and probably affords materials for the support of the volcanoes that exist in that country." So far from this being the fact, the inhabitants of Iceland are destitute of fuel, and obliged to use the dried bones of fish; nor is there more reason to believe that beds of coal have supplied the fires of Ætna with fuel for three thousand years, as Mr. Jameson supposes.

Carbonaceous matter exists in small quantities in some primary and transition mountains. A particular kind of hard shining coal, that burns without flame or smoke, to which mineralogists give the name of anthracite, is sometimes found in these mountains. This kind of coal appears to graduate into the substance called plumbago, black lead, or graphite, which consists of carbon united with a small portion of clay and iron. Common coal is also observed in some situations to graduate into plumbago, but of a less adhesive kind than that found in transition mountains*. Plumbago, anthracite, and many kinds of hard coal, are so completely mineralized as to present no appearance of their vegetable origin; but in common coal, and in wood coal, the existence of vegetable remains is frequently perceptible, and the strata over coal abound with impressions of ferns and larger plants. It is now generally admitted that common coal was derived from the partial decomposition of vegetable matter: many circumstances favour this opinion; but from whence did the vegetable tribes originally derive the carbon of which their solid parts are principally composed? Carbon either previously existed in nature, or trees and plants had the power of forming it from more simple elements. Neither of these opinions is improbable, nor are they at variance with each other. If carbon be a compound substance, of which hydrogen is a constituent part, it may be formed by the process of vegetation, or it may exist also in the mineral kingdom, independent of organic productions. Carbon united with oxygen forms carbonic acid, a constituent part of all limestone mountains. Bituminous matter which contains carbon exudes, according to Dolomieu, from recently erupted lava. Bitumen was observed by Denon coating the stones in the Gulf of Messina, which became hard, and formed a solid incrustation. This phænomenon was probably connected with the volcanic fires of Ætna. The pitch lake of Trinidad, the asphaltum of the Dead Sea, and the naphtha of Persia and other parts of Asia, may have a similar connection with subterranean fire, as volcanoes or volcanic products exist in countries where they occur.

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* Plumbago is frequently produced in our iron furnaces, forming a thin incrustation over iron, where it has been in contact with coal during fusion.

Morier says there are many volcanoes in Persia which only emit smoke and mephitic vapour.—(*Travels in Persia.*)

Though the carbon in primary mountains may be derived from the mineral kingdom, there can scarcely remain a doubt that wood coal and common coal are of vegetable origin. Wood coal or brown coal is found in low situations, and appears to have been formed of heaps of trees buried by inundations under beds of clay, sand, or gravel. The woody parts have probably undergone a certain degree of vegetable fermentation, under the pressure of the incumbent earthy matter by which they have been carbonized and consolidated. In some specimens of this coal, the vegetable fibre or grain is perceptible in one part, and the other is reduced to mineral coal. The vegetable principles which this coal contains, united with bitumen and charcoal, have been already stated. In black or common coal, the vegetable extract and resin are destroyed, and the charcoal and bitumen alone remain; but wood coal and common coal bear in other respects too close a resemblance to allow us to ascribe to them a different origin, though they were probably formed from different tribes in the vegetable kingdom, and under different circumstances.

The recent experiments of Dr. MacCulloch go far to prove that the bituminization of wood may be effected by water*. The further conversion of bituminized wood into true coal may possibly be the effect of consolidation produced by the agency of fire.

Wood coal is found in considerable quantities at Bovey Heathfield, near Exeter. Several beds of coal are separated by strata of clay and gravel; the lowest is seventeen feet thick, and rests on a bed of clay, under which is sand resembling sea sand. The coal in contact with the clay has a brown colour, and appears intermixt with earth. In other parts the laminæ of the coal undulate, and resemble the roots of trees; in the middle of the lowest stratum the coal is more compact, and is of a black colour, and nearly as heavy as common coal. It is supposed that the species of wood of which Bovey coal was formed, is fir, as stumps of large fir trees, fixt by their roots in the ground, may be observed in the vicinity. These trees were probably deposited by successive inundations, when the higher parts of the country were covered with primæval forests and peat moors.

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* Transactions of the Geological Society, vol. ii.

A great repository of this kind of coal exists near Cologne: it extends for many leagues: it is fifty feet in thickness, and covered with a bed of gravel from twelve to twenty feet deep. Trunks of trees deprived of their branches are imbedded in this coal; which proves that they have been transported from a distance. Nuts, which are indigenous to Hindostan and China, and a fragrant resinous substance, are also found in it. A similar resinous substance occurs in the Bovey coal, and was discovered with fossil wood in cutting through Highgate hill. Mr. Hatchett, by whom it was analysed, has given it the name of retinasphaltum.

In wood coal we may almost seize nature in the fact of making coal before the process is completed. In some peat moors the lower beds are compact, and approach nearly to the nature of coal; and it is said that peat has been discovered passing into mineral coal. These formations of coal are probably of more recent date than common coal, though their origin must be referred to a former condition of the globe, or to some grand catastrophe which has brought to northern latitudes the vegetable productions of tropical climates.

Granting the vegetable origin of coal, we shall have no difficulty in accounting for an accumulation of carbon sufficient for its formation in every district where coal has been discovered. In the early ages of the world, the greater part of its surface was a dreary solitude covered by vast forests, and by marshes and peat moors, which were constantly accumulating vegetable matter. This might be carried away by great inundations, and deposited in hollows which formed temporary lakes: as these became dry, the vegetable matter which floated on the surface of the water would be left on the ground. Before fresh vegetable matter was formed, subsequent inundations might cover the former deposition with beds of sand or clay. Other depositions of vegetable and earthy matter might follow in succession, and fill up the hollow which formed the temporary lake.

It is a curious fact in the natural history of the earth, that regular coal strata appear to be principally if not exclusively confined to the colder or more temperate regions of the globe between the latitudes of 35 and 65. This would seem to indicate that the particular vegetables from which coal was formed could not flourish in hot and dry climates.

The greatest difficulty respecting the origin and formation of coal strata is the regularity with which they are arranged, and the frequent succession of thin strata or laminæ of coal in the same coal field. These are too thin and too regularly arranged to be formed by large vegetables, except in a state of perfect decomposition. They may have originated from small aquatic plants or mosses growing in the place after each inundation; and the occurrence of the same peculiar kind of fire clay* under each bed of coal, may favour the opinion that this was the soil proper for the production of those vegetables from which coal was subsequently formed. In most coal fields there are thin strata of coal-smut or carbonaceous and other particles intermixt, which seem also to favour the opinion of the formation of coal strata by successive inundations:

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* This clay is more or less indurated, but it still retains its peculiar quality of resisting the action of fire.

—the subsequent consolidation of the coal may be less difficult to conceive.

By vegetable fermentation and compression, and by the evolution of heat from both these causes, the various strata may have consolidated. And if, with the Plutonists, we admit the action of central subterranean fire, it may also have contributed to the more complete destruction of vegetable organization.

Pressure and time alone may be sufficient to produce these effects partially, as is proved by the complete consolidation of loose materials left in coal mines when the supports are removed and the upper strata sink down. In a few years scarcely a trace of former operations remains. In contemplating natural causès, we are too apt to measure their power by the results of artificial processes, and by observations continued for a short portion of human life. The substances found in the neglected vessels of the chemist often prove to us that changes in the physical properties of bodies are effected by time, which it would be difficult to imitate in common experiments*.

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* The effects of compression are exemplified in France by a mode of making building stone from loose materials or

Many beds of shale in the coal strata abound with pyrites as well as with carbonaceous and bituminous matter. By exposure to air and moisture the pyrites is decomposed, and the sulphuric acid uniting with the alumine, forms the well known salt called alum; which is seen efflorescing in some coal mines, and might be formed in others were it thought desirable, and due precautions were used. Aluminous schistus or alum-slate resembles some varieties of coal shale. The enormous bed of this rock in the North Riding of Yorkshire is evidently part of a series of coal strata, being covered with sand-stone, coal, and iron-stone. The external characters of the stone are precisely similar to those of some of the coal shales in the West Riding; but it contains different organic remains, and I am inclined to consider it as a distinct formation. The alum slate of Yorkshire has a very dark gray colour, a slaty structure, and rather

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rubbish moderately moistened, and put into a case or mould. By two or three strokes with a stamping-engine, the parts are made to cohere so firmly, that the rubbish is converted into a hard stone, and is made use of in the construction of large buildings.—*Birkbeck's Tour through France.*

rather a silky lustre; it splits by exposure to the air into very thin laminæ. It varies in hardness; but all the specimens which I have examined are softer than roof-slate. Having recently visited that district, a further account of this rock will be given in the chapter on the Geology of England. The particular advantage which the country near Whitby in Yorkshire presents for the manufacture of alum is derived from the alum rock rising in precipitous cliffs, which afford facilities for working and burning the stone. Though many of the coal shales might yield an equal quantity of alum, the difficulty of raising them to the surface would in most situations be too great to repay the expense. The alum-stone is piled in vast heaps, and set fire to; a slow combustion is continued for several months by the inflammable matter combined with the stone. The saline contents are extracted by solution, a small quantity of potash is added, and the salts are crystallized by evaporation.

In the coal mine at Hurlett, near Glasgow, a formation of alum is taking place by the natural decomposition of a bed of pyritous shale that forms the roof of the coal. "The coal, with the superincumbent roof, dips just enough to afford a free passage for the water, and the mine is worked (contrary to the usual practice) from the rise to the dip: hence all the workings are necessarily kept perfectly dry. For three centuries has this colliery been in work, and it now presents an excavation, the area of which is nearly a mile square, with pillars of coal at the usual intervals, in order to support the overlying beds, the thickness of which is on an average about thirty fathoms. The air circulates slowly through the whole of this space by means of such of the old shafts as still remain open; and in consequence a slow decomposition of the roof is perpetually going on. This process, however, is so gradual, that in no part has the slate been hitherto removed. The first action of the air is to cause a thin flake to come off from the roof: and fall upon the dry floor; in this last situation the decomposition makes further progress, and by degrees assumes the appearance of a light spicular efflorescence. Succeeding flakes go through a similar process, and in time the whole space, up to the very roof itself, is completely filled: the current of air being then obstructed, all further decomposition of course ceases till the effloresced portion is removed."—*Phil. Journal, vol. xvi.*

CHAPTER IX.

ON THE UPPER SECONDARY ROCKS, AND THE STRATA CONTAINING THE REMAINS OF RIVER FISH AND QUADRUPEDS.

Depth of Secondary Strata lying between the Surface and Primary Rocks.—Magnesian Limestone.—Singular Contortions and Configurations of this Rock.—Roe-stone.—Formation of the imbedded Globules.—Chalk Rocks and Flint.—Beds of Gypsum: Opinion respecting their Formation.—Gypsum of Derbyshire and Nottinghamshire.—Bones of Quadrupeds and Shells of River Fish in Strata over Chalk.—Alternation of Strata near Paris, containing marine and fresh-water Shells.—Geological Inferences.—Fresh-water Lakes of America and Ancient Europe.

THE secondary rocks, which form the subject of the present chapter, are the last in the series descending from primary mountains to the sea coast. Primary and transition rocks may be supposed to lie buried deep under them in flat countries. It would be a curious subject of investigation to determine the real depth to which it might be necessary to sink in such countries, in order to arrive at primary rocks. Though it is impossible with our present means to penetrate so far into the earth, yet, by a knowledge of its structure, we may sometimes determine the depth of different rocks without breaking the ground. If we suppose plate I. fig. 1, to represent the section of a country over which we are to travel from the secondary rocks at 6 to the granitic mountain *a*, by observing where the rocks 5, 4, 3, and 2 make their appearance from under each other, and noticing their breadth and angle of elevation, we may ascertain the thickness of each rock, and the depth of the granite from any part of the surface. This, however, can only be done in situations where the continuity of the rocks and strata is not broken by what miners call faults or dykes, which throw them out of their regular position. A representation of the succession of rocks, as they rise to the surface, through the counties of Northumberland and Durham, is given plate VII. fig. 1, and a section of the strata nearly fourteen hundred yards in depth.

In the succession of upper secondary rocks in different countries there is great diversity, but they agree in being generally more earthy and soft than the lower secondary rocks. They consist principally of coarse sand-stones, earthy lime-stone, calcareous sand-stone, and chalk, and are particularly distinguished by the variety of organic remains which they contain.

Stratified lime-stone and calcareous sand-stones separate coal districts from chalk on the south-eastern side of the island. They extend from Dorchester to Northamptonshire, and on the eastern side of Leicestershire, Nottinghamshire, Yorkshire, into part of Durham and Northumberland. The earthy lime-stone in this range is frequently of a yellow colour, and some of the beds contain more than 40 per cent. of the carbonate of magnesia. Few organic remains occur in the magnesian lime-stone; it is generally distinctly stratified, and the strata are nearly horizontal, but may be perceived to dip to the east. In some situations at a distance from this range, hills of magnesian lime occur, the beds of which are elevated and singularly contorted, and the stratification indistinct. Some beds of the magnesian lime-stone are worked for building-stone, which is very durable, and resists the action of acids and the decomposing effects of atmospheric influence better than any other calcareous stone. York minster and the walls of that city are built of this stone. In the county of Durham, near Sunderland, the magnesian lime-stone frequently presents the most singular configurations; it also yields a fœtid smell when struck with a hammer, being of that variety called by mineralogists swine-stone. See the chapter on the Geology of England.

It is erroneously supposed that magnesian lime is injurious to land, and unsuitable for agricultural purposes; the fact is, that a small quantity will produce a more powerful effect than a greater quantity of common lime.

Various beds of calcareous sand-stone, marle, sand, and roe-stone occur between the above lime-stone and chalk. The most important of these is the *oölite* or roe-stone, a species of lime-stone which derives its name from small globules imbedded in it, supposed to resemble the roes of fishes. Portland-stone and the ketton-stone in Northamptonshire are varieties of roe-stone; the former is procured at the isle of Portland, and extensively used for public edifices in the metropolis. It consists of lime and a small portion of silex, clay, and the oxyd of iron. Portland-stone extends as far north as Hackness, north of Scarborough, in Yorkshire.

Portland-stone contains shells and other organic remains, but the small globules by which it is distinguished are the result of crystallization. I think this is demonstrated by an analogous formation in beds of calcareous sand or marle, which occur in the magnesian lime-stone near Sunderland. These beds contain numerous balls, varying in size from a small pea to eight or nine inches in diameter. These balls have a crystalline radiated structure: in many instances the process of their enlargement has been checked by meeting with other balls, which has prevented their extension in that direction, and two or more balls have united, representing spheres with segments cut off, and joined at the place of section. Had the base of the Portland-stone remained soft like the calcareous marle at Sunderland, in all probability the globules would have enlarged by a similar process.

The beds of sand and sand-stone with clay, which separate the oölite from chalk, extend with a considerable degree of regularity over the south-eastern side of England, but varying in their thickness. It has been observed that different organic remains belong almost exclusively to particular strata, and the same kind are found in the same stratum throughout its whole extent, as far as has been traced. In the midland and northern counties less regularity can be distinguished, and many of the strata are entirely missing which occur in the south.

Chalk is a soft white calcareous stone, too well known to need a particular description. It has been observed that chalk occupies situations near the sea, and has a low comparative elevation. Chalk is common in the south-eastern part of England, and in the lower districts of Europe at no great distance from the Baltic and the German ocean; but I believe no calcareous stone exactly similar is found in the south of Europe, or in Asia or Africa, though some earthy lime-stones have been called chalk by travellers. Neither chalk nor roe-stone was discovered by Humboldt in South America, nor have they been observed in any part of the United States.

The chalk hills of England spread through many of the eastern counties from Dorsetshire to the hills called the Wolds in the East Riding of Yorkshire. The upper or soft chalk containing flint is from four hundred to six hundred feet in thickness; in many parts of its course it lies in thick beds indistinctly stratified. Nodules of flint are arranged in chalk in parallel layers at different depths under each other.

Flint is a well known substance, composed almost entirely of siliceous earth. The curiosity of geologists has been excited to discover in what manner nodules of this substance came into the midst of calcareous rocks. In Derbyshire the upper beds of compact lime-stone are divided by seams of siliceous earth, called chert, which nearly resembles flint.

It is not improbable that siliceous earth may have permeated the lime, and been afterwards separated by chemical affinity, and collected in fissures and cavities of the calcareous rock. The passage of one mineral substance through another, even in a solid state, appears to be confirmed by numerous analogous facts, however difficult it may be to explain. An experiment of Peltier may throw

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some light on the subject: he mixed a solution of alum with clay, and formed the whole into a paste. The mass was broken when perfectly dry, and the alum was observed collected into detached crystals in different parts of the clay, being separated by the power of chemical affinity and crystalline arrangement, which the tenacity of the clay could not destroy.

It is the opinion of some geologists, that siliceous earth is derived from the flesh of those animals whose shells have formed calcareous rocks. Mr. Parkinson, who has bestowed much attention on this subject, states as an objection, that "there does not appear to be a single instance in which the animal remains are impregnated with silex. On the contrary, the substance of all these fossils has become calcareous spar, and their cavities have been filled with flint; thus plainly evincing that sufficient time must have elapsed for the crystallization of the calcareous spar, previously to the infiltration of the flint. In no instance does the flint, although in contact with the spar, appear to become mixt with it. The reverse of this is the case with the chalk, since the latter may be seen in almost

most every degree of union with the flint, from being blended with the substance, to being united with its surface, and forming the white coat of flint." I cannot think these facts militate against the opinion that lime and flint are convertible into each other by natural processes. When substances crystallize, the different constituent parts are always disposed to separate, and present each substance in its simplest state: hence we might expect that calcareous crystals or spar would be free from any admixture of flint, as they are described to be by Mr. Parkinson. It is well known that shells of echini, which once were calcareous, are found entirely composed of flint; and it is the common belief of working miners, that lime and flint are changed into each other. This belief has been treated with contempt: but before we hastily reject the opinions of practical men, we should do well to consider whether such opinions are in opposition to facts, or are only at variance with existing theories. Until we know whether the metallic bases of the earths be simple substances, or compounds formed of more elementary principles, it would be premature to deny the possibility of their conversion into each other by natural processes with which we are at present unacquainted.

The lower beds of chalk are harder and more compact than the upper, and contain neither nodules nor layers of flint. This is considered by Mr. Parkinson as a distinct formation: he says, "hardly a single fossil has been found in it which has been met with in the soft chalk, or any other stratum." The lower chalk is properly an earthy limestone, and is sometimes used for building-stones.

In the order of succession proceeding from the lowest primary rocks to the upper secondary rocks, the two beds of hard and soft chalk have been considered as the last or uppermost of the solid rocks or strata. Over the chalk occur thick beds of clay and sand in various situations, and also partial formations of strata, which appear to have been deposited at the bottom of extensive lakes of fresh water: they will be subsequently noticed.

Beside the rocks of this class already enumerated, there is another substance, sulphate of lime, gypsum, or plaster stone, which, though not very abundant, is met with in various situations among secondary rocks.

It was stated in a preceding chapter, that gypsum is associated with rock-salt; but it is also found where neither rock-salt nor salt springs exist.

Gypsum, or sulphat of lime, consists of 33 parts lime and 46 of sulphuric acid, combined with 21 parts of water. When compact it is called alabaster*; when perfectly crystallized, selenite: some varieties of gypsum are fibrous, others foliated. It has probably been formed by the decomposition of iron pyrites, which supplied the sulphuric acid that afterwards united with the subjacent lime. As a confirmation of this, it may be observed that the marle and sand over gypsum, in many parts of England, contain a large quantity of red oxyd of iron. Gypsum is distinguished from lime by its softness: it does not effervesce with any acid, being already saturated with the sulphuric. Native sulphur is sometimes found intermixt with gypsum: in these cases, probably, the sulphuric acid has been decomposed by the presence of animal or vegetable matter during the decomposition of pyrites.

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* Calcareous stalactite is sometimes called alabaster.

Gypsum has been occasionally discovered in primary and transition mountains: it belongs more peculiarly to secondary stratified rocks, but may be formed in all situations where lime and sulphuric acid exist near to each other*.

Though gypsum rarely contains shells, bones are sometimes found in it: hence it has been supposed that sulphuric acid destroyed the traces of organization in the former, which consist of lime and carbonic acid, but acted with less force on bones, which contain phosphoric acid.

The beds of gypsum at Chellaston, in the south of Derbyshire, are situated near the vale of Trent, in hills of low elevation, which may be considered as forming the northern boundary of the vale. The gypsum beds on the other side of the vale are in hills, which form the southern boundary near the junction of the rivers Soar and Trent. The gypsum is covered by marle and gravel containing numerous organic impressions, among which I collected belemnites, gryphites, joints of the pentacrinite, bivalve shells which appear compressed, and one specimen of a nummulite. The principal beds are of considerable thickness; the stone is compact, and where it is not discoloured by an intermixture of red marle, or by stripes of greenish marle, it is white and translucent. Thin strata of beautiful white fibrous gypsum occur in marle, at Clifton, on the south side of the Trent, near Nottingham.

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* The disciples of Werner have very ingeniously assigned particular stations for different kinds of gypsum, but their descriptions are singularly confused: thus, Mr. Jameson places what he calls the first (flœtz) gypsum over the first (flœtz) lime-stone, and the second flœtz gypsum over the second sand-stone: and then informs us that the gypsum of Cheshire belongs to the latter, though it is associated with rock-salt, and red sand-stone, which he before states lie under the first flœtz lime. Of the gypsum of Derbyshire he says, "to what formation it belongs we know not, as no well educated geognost has ever communicated any observations respecting it."

The geological situation of the Derbyshire gypsum may be represented as situated in the upper secondary strata, separated from the mountain lime by intervening coal districts on one side, and from the stratified magnesian lime by sand-stone on the other side*.

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* A disciple of Werner would scarcely hesitate in denominating this the second flœtz gypsum. The sand-stone west of Nottingham has many characters similar to those of the second sand-stone formation described by Mr. Jameson.

No organic remains have been discovered in the gypsum of Derbyshire or Nottinghamshire, though they are abundant in the gravel and marle which cover it. From the latter circumstance, it seems probable that it is a distinct formation from that of Cheshire, the covering of which contains no shells, according to the description of Dr. Holland, a native of that country.—(Holland's Survey of Cheshire.) Chalk was considered as the latest formation of lime-stone; but in some situations calcareous strata have been discovered over chalk, which contain the remains of fresh-water animals, and these strata are again covered by others of marine origin.

In many of the southern counties of England, the chalk is immediately covered by a bed of clay more than one hundred and twenty feet thick: in some parts it is called the London clay, being the stratum which extends over the vale of Thames where London is situated. It constitutes the basis of Highgate-Hill, where it has lately been cut through in forming the intended tunnel. Organic remains of nautili and other marine animals occur in this clay, and also fossil wood. This clay is covered by gravel and marle. In this marle the bones of the elephant, the hippopotamus and the elk are not unfrequently found. In the Isle of Wight there is a series of strata over the clay containing the remains of fresh-water fish, and many shells similar to what are found in the strata over chalk near Paris.

The plaster quarries at Montmartre, in the environs of Paris, are celebrated for their numerous and remarkable organic remains. Montmartre is elevated about eighty yards above the level of the Seine, the summit is covered with vegetable earth, under which is a bed of sand mixt with pebbles of flint. Horizontal strata of marle, earthy lime-stone and gypsum succeed each other. The quarries, according to M. Sage, may be considered as divided into three large beds: the first, called by the workmen "haute masse," is often more than fifty feet thick, and is distinctly stratified: it rests on a bed of blueish clay intermixt with marle. The second bed is fourteen feet thick in contiguous strata; this also rests on marle. The third bed, called "basse carrière," is about fourteen feet thick, but divided into six strata, separated

rated by layers of marle. The lowest is on a level with the plain, and rests on chalk.

The following extracts from the Géographie Minéralogique des Environs de Paris, par M. Cuvier, tom. i. will more particularly explain the appearance and succession of the strata.

"The country in which the capital of France is situated is perhaps the most remarkable that has yet been observed, both from the succession of different soils of which it is formed, and from the extraordinary organic remains which it contains. Millions of marine shells, which alternate regularly with fresh-water shells, compose the principal mass. Bones of land animals, of which the genera are entirely unknown, are found in certain parts; other bones remarkable for their vast size, and of which some of similar genera (*quelques congenères*), exist only in distant countries, are found scattered in the upper beds. A marked character of a great irruption from the south-east is impressed on the summits, (*caps*) and in the direction of the principal hills. In one word, no canton can afford more instruction respecting the last revolutions which have terminated the formation of the present continents."

Though chalk is the foundation rock of the country for a considerable extent round Paris, it only rises to the surface in a few situations, being covered by the other strata in the following order, beginning with the lowest from the chalk, or lowest stratum :—

1 Chalk and flint.
2 Plastic clay and lower sand.
3 Coarse lime-stone, or
* *Calcaire grossière.*
4 Lower marine sand-stone.
6 Lower fresh-water strata.
7 Gypseous clay and gypsum containing bones of quadrupeds.
8 A bed of oysters.
9 Sand and sand-stone without shells.
10 Superior marine sand-stone.
11 Mill-stone without shells and argillaceous sand.
12 Fresh-water formation including marles, mill-stone, and fresh-water shells.
13. Alluvial soil, antient and modern, including pebbles, pudding-stone, black earth (*les marnes argilleuses noires*), and peat.

* In some situations, on the same level with 3 4 is a bed of calcareous stone penetrated by silex without shells; it occupies the place of 3 and 4 where it occurs.

The total thickness of the different beds and strata over the chalk, as given in an ideal section of the country in the first tome, is about one hundred and fifty metres, or near four hundred and ninety feet.

The inferences which Cuvier and his associate Brongniart have drawn from the organic remains of marine and fresh-water animals found over each other at this place, are comprised in the following summary account of the seas or lakes of salt or fresh water, which they suppose have ultimately covered the surface round Paris, and deposited the different beds enumerated above.

1st. A sea which deposited an enormous mass of chalk, with molluscous animals of a particular species. (No. 1. chalk and flint.)

2d. The sudden variation of this deposition, and the succession of one entirely different, ("d'une toute autre nature,") which deposited only beds of clay and sand*. (No. 2. plastic clay.)

3d. Another sea soon succeeded (or the first returned again), producing new inhabitants; a prodigious quantity of testaceous mollusci, different from those in chalk, forming thick beds at the bottom of this deposition, which are principally composed of the coverings of testaceous mollusci ("des envelopes testacées"). (No. 3 and 4. calcaire grossière.) This sea soon after returned.

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* The editor of the Journal de Physique observes that fossil wood is discovered in these beds.

4th. The surface was covered with fresh water ("eau douce"), and beds were formed alternating with gypsum and marle, which enveloped the debris of animals bred in the lakes, and the bones of those living on its banks. (No. 6 and 7.)

5th. The salt water returned, and supported first a species of animals with bivalve shells; and others with turbinated shells ("coquilles turbinatées"); these shells ceased to be formed, and were succeeded by oysters. An interval of time elapsed, during which a considerable deposition of sand took place: no animals then existed in these lakes, or their remains have been entirely destroyed. (No. 8 and 9.)

6th. The various productions of the second lower sea ("la mer inférieure") reappear, and we find on the summit of Montmartre, Romanville, &c. the same shells which occur in the middle of the coarse earthy lime-stone ("calcaire grossière"). (No. 10 and 11.)

7th. At length the sea entirely disappeared for the second time from the lakes, and pools of fresh water ("mares d'eau douce") supplied its place, and covered with their inhabitants almost all the summits of the adjacent banks, and the surface of some of the plains which separated them. (No. 12 and 13.)

Cuvier and Brongniart further state, that "the lowest beds of gypsum were deposited in a sea analogous to the ocean, because it supported the same animals." In this statement it is assumed that the sea has repeatedly risen and disappeared, and fresh water has supplied its place, in order to explain the succession of marine and river shells found in the different strata over each other. There is, however, no reason to believe that such a succession of strata exists, except in countries where chalk is found. These strata are local and partial formations.

La Metherie, the editor of the Journal de Physique, supposes that these fresh-water shells, and the remains of quadrupeds, were carried by inundations from the land, and deposited in their present situation by marine currents.

CHAPTER X.

GENERAL OBSERVATIONS ON THE FORMATION OF SECONDARY ROCKS.

It has been admitted with too great latitude by geologists, that the secondary strata are principally formed of mechanical depositions, or of the fragments of other rocks broken down and comminuted by the agency of water, and subsequently consolidated. It cannot be doubted that many of the secondary strata contain water-worn particles and fragments: it is also evident that the mountains and higher parts of the globe were once more elevated than at present; and therefore it follows, that depositions from them were spread over the lower grounds, and have formed part of many secondary beds and strata. Some sand-stones appear to be entirely formed of the debris of pre-existing rocks broken down and cemented together, as in various conglomerate rocks. The sand rock, on which the town and castle of Nottingham are situated, has evidently been formed in this manner: it is a very friable sand-stone, slightly cemented by oxyd of iron and clay, containing numerous smooth pebbles disseminated through the mass, and in the horizontal seams there are layers of white quartz pebbles. It perhaps might be proper to call such rocks tertiary. There are however numerous strata among the secondary rocks which are highly crystalline, consisting almost entirely of pure granular quartz, and others of crystalline lime-stone. Such strata must have had a mode of formation analogous to that of the primary rocks, and cannot be considered as mechanical depositions. There is a stratum of siliceous sand-stone forming one of the lower beds in the Yorkshire coal field, which is beautifully white and crystalline, and is applicable to the manufacture of some kinds of glass.

It is also deserving notice, that in some of the secondary strata no organic remains occur, though they are found both in the strata above and below. We must either suppose, in these instances, that organic beings had ceased to exist in the places where such strata were formed, or that some natural process had obliterated all trace of their existence.

It is observable that calcareous strata contain remains of marine animals, but seldom if ever those of vegetables. Argillaceous strata contain remains both of vegetables and aquatic animals. In siliceous strata organic remains more rarely occur, and these are generally of large vegetables, completely penetrated with silex, with scarcely any trace ot their vegetable origin but the form, and sometimes a thin incrustation of carbonaceous matter.

I have before stated my opinion that the secondary strata are local formations, and that some of the upper strata were formed in detached lakes. But I believe a more enlarged view will be sufficient to prove that all the stratified rocks above the red sand-stone and alpine lime-stone, are local formations, which had their origin in detached hollows or seas of great extent, and are limited to certain portions of the globe. The observations of travellers in various parts of the world incontestably prove that these formations are local. I am even inclined to consider the red sand-stone and the alpine lime-stone also as local formations, but of much greater extent than any of the strata above them; and I further think that, if this view of the subject were admitted, it would relieve geologists from the greatest difficulties under which the science labours at present, and would go far to establish a simple and perspicuous system, which will at once account both for the similarity and the diversity of rock formations in various parts of the world. If the mountains were once much higher than at present, it must be admitted that, before the formation of the secondary strata, the valleys and hollows were deeper in a far greater proportion, because, to the height of the surrounding mountains, we must add the whole depth of the secondary strata which were then wanting. By whatever process the secondary strata were formed, the existence of organic remains in them incontestably proves that they were deposited in succession; and the regularity with which they are spread, further proves that the greater part were deposited in a fluid medium.

As there are indubitable proofs that the water once covered all the existing continents, it follows that, when the ocean retired, or, which is the same in effect, when the dry land emerged from the sea, vast inland seas or lakes would be left, at the bottom of which the secondary strata were formed. As the sea retired further, the higher grounds being left dry, these large inland seas or lakes would be contracted, and a number of smaller isolated lakes would occupy the lowest cavities and depressions; in each of which separate depositions of strata might take place. The lower strata would therefore be the most widely spread, and the upper would constitute independent formations of greater or less extent, in which their might be great similarity in some situations, and much diversity in others. Now such is found to be the fact. The above I consider not as hypothetical assumptions, but as legitimate inferences from indisputable facts, which will go far to explain the formation of the upper surface of the globe in a simple and intelligible manner, consonant with its present physical structure.

Were I to proceed a step further, and inquire respecting the origin of the matter that forms the secondary strata, I must advance hypotheses which I wish to keep distant from facts. I am however inclined to believe that the interior of the earth is the great storehouse and laboratory from whence all the elements of the rocks that now cover its surface were originally supplied. The numerous extinct volcanoes that have been dormant from remotest times had once an important use in the œconomy of the globe. Their mouths or craters are of immense size. The ancient mouth or crater of Teneriffe occupies a space of twelve square leagues. Its surrounding walls of lava are at present distinctly visible. The observations of Humboldt and numerous travellers confirm the assertion, that "there is no active volcanic crater at all to be compared in size with those that are extinct*."

It cannot be doubted that the quantity of matter ejected was proportionate to the mighty openings through which it was thrown out. When the present continents were covered by the sea or by lakes, these volcanoes were all submarine, and poured forth their torrents of water impregnated with silex and clay, which probably have formed many of the secondary strata, or by which the sediment already deposited in these lakes became impregnated and consolidated. As it is only by analogy that we can with any appearance of probability speak of such formations,

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* See a very interesting and perspicuous account of Teneriffe by the Hon. H. G. Bennet, in the second volume of the Transactions of the Geological Society.

tions, it may be proper to remark, that in all the instances in which loose sands are known to be formed into stone, it appears to be effected by infiltration from waters in the vicinity of subterranean fires, as on the shores of Sicily, of Portugal, and probably of Guadaloupe;—and further, that the only instances of silex held in solution by water are furnished by subterranean heat in the hot springs of various parts of the world. Let us now take a view of what is going on at present in lakes, or even artificial pools of water, in which we find in the course of years thick beds of sediment formed and spread over the bottom, and containing fresh-water shells and parts of vegetables. These I consider as similar to the beds of argillaceous shale in secondary rocks, and to that enormous deposit which forms the aluminous schistus at Whitby, in which numerous ammonites and nautili with pieces of fossil wood are imbedded. The animals, doubtless, lived and died in the places where they are found, and the wood was washed down from the higher parts of the country*.

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* An animal exactly similar to the ammonite exists at present in the mud of the river Tees. It differs in no respect

The beds of clay or mud, with their included fossils, have been consolidated by some process different from mere gradual desiccation. The strata of crystalline sand-stone and lime-stone strata, with which they are covered, appear to be formed in a different manner; and I am inclined to refer their origin to a deposition from subterranean waters impregnated with siliceous or calcareous earth, and thrown out of the immense craters of ancient volcanoes, like the torrent which flowed from the summit of Etna in 1794, and the aquatic eruptions from the vast volcanoes in the Andes.

If the matter of which the secondary strata are principally formed were ejected from the interior of the earth, the space it had occupied might be filled by the retiring waters of the ocean, which all geologists are agreed had once a higher level than at present.

In proportion to the diminution of the waters of the large lakes the number of small lakes

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spect but in size, being about half an inch in diameter. On examining it with a lens, and comparing it with a great variety of ammonites at Whitby, there were some with which it exactly agreed in the minutest particular of form, curvature, and indentation of the spirals. We cannot therefore doubt that the habitudes of both animals were similar.

lakes would increase, and also the number of limited independent formations, till we come to the more recent, whose extent we can trace by basins or hollows of comparatively small size. One large lake may have originally covered England and part of Europe when the red sand-stone and alpine lime-stone were formed; but as the water retired the succeeding formations would be more limited.

Many of secondary strata are known to be local or independent formations;—of this kind are the fresh-water formations over the chalk;—but by extending this mode of formation to the lower rocks, we shall be relieved from the difficulty of accounting for their disappearance in various countries where they ought to be found if they were formed universally over the globe. We shall further be relieved from the necessity of supposing universal inundations of salt and fresh water alternately succeeding each other. Admitting the existence of numerous detached lakes over our present continents, and the occasional convulsions which have fractured the surface of the globe, it will not be difficult to conceive that many of these lakes have been alternately opened and closed by the overthrow of the surrounding mountains or embankments. We ought also to recollect, that when the secondary strata were deposited, and filled up the bottom of many of the lakes, the water would be thrown again over the surface of the surrounding country; and from this cause we may explain many of the alternations of dry land and sea, without recurring to the forced assumption of the whole ocean rising from its bed to form strata of comparatively small extent.

The position of the strata in the Isle of Wight, which will be subsequently noticed, demonstrates that some great convulsion has upheaved from their foundations and overturned the whole mass of the chalk rocks, and the strata that cover them not less than three thousand feet in thickness. At the period when this was effected, it is not improbable that England was separated from the continent. See chapter on the Geology of England.

On the continent of America, nature acts upon a magnificent scale. Were her operations attended to, they might illustrate many interesting facts in geology.

The lakes of North America are seas of

fresh water more than fifteen hundred miles in circuit: these are placed at a considerable elevation above the Atlantic, and at different levels. They unite by small streights or rivers, which have a rapid descent. On some of them are prodigious waterfalls, which are constantly enlarging and shortening the passage from one to the other, and will ultimately effect the drainage of the upper lakes. The falls of Niagara are well known. The water is divided by a small island, which separates the river into two cataracts, one of which is six hundred and the other three hundred and fifty yards wide, and from one hundred and forty to one hundred and sixty feet in depth. It is estimated that six hundred and seventy thousand tons of water are dashed every minute with inconceivable force against the bottom, and are undermining and wearing down the adjacent rocks. Since the banks of the cataract were inhabited by Europeans, they have observed that it is progressively shortening the distance from lake Erie to lake Ontario. When it has worn down the intervening calcareous rocks and effected a junction, the upper lake will become dry land, and form an extensive plain, surrounded by rising ground, and watered by a river or smaller lake, which will occupy the lowest part. In this plain future geologists may trace successive strata of fresh-water formation, covering the subjacent crystalline limestone. The gradual deposition of minute earthy particles, or the more rapid subsidence of mud from sudden inundations, will form different distinct beds, in which will be found remains of fresh-water fish, of vegetables, and of quadrupeds. Large animals are frequently borne along by the rapidity of the current, and precipitated down the cataracts; their broken bones mixt with calcareous sediment, may form rocks of calcareous tufa where the waters first subside after their descent. Bones of quadrupeds are found thus intermixt in the calcareous rock at Gibraltar. Perhaps there was a period when the branches of Mount Atlas were united with the mountains of Spain, and the Mediterranean mixed its waters with the Atlantic through a narrow passage like that of Niagara. The two seas would then have a different level, and a stupendous cataract might exist near the rocks of Calpe, and bury under its waves many of the animals that attempted to cross the current. From the intermixture of these bones with calcareous sediment, the present rocks, with their osseous remains, may have originated.

These calcareous strata have probably been raised by a sudden subterranean explosion, which opened a passage for the waters of the Atlantic, and reduced both seas to their present level. Such an explosion, nearly in that situation, but less violent, took place in 1755, which shook in the same hour all northern Africa with the southern kingdoms of Europe, and was felt on the distant shores of the American islands.

It has been observed that chalk is principally confined to the coasts of England and France, and to the islands and countries bordering on the German Ocean and the Baltic. If the southern parts of England were once united to France, the German Ocean would form an extended basin, into which all the waters in the Baltic, with the Rhine and the principal rivers of northern Europe, would flow. The central parts of England, and the Carpathian mountains, and the mountains in the central parts of France, might form the borders of this lake. If it were nearly closed at its northern extremity, it might be salt in a much less degree than the waters of the ocean, and require different inhabitants from those of the sea or of rivers; and it is not a little remarkable that the animal remains found in chalk differ from those of any other known rock or stratum.

The chalk said to be found in Spain and the south of France, with fresh-water shells over it, may have been formed in similar lakes. From every circumstance, we appear warranted in concluding that chalk and the strata over it are local formations. By extending the same mode of reasoning to the strata under the chalk, we shall perceive the cause why the secondary rocks in Europe differ so much from those which cover the primary mountains of America.

CHAPTER XI.

ON THE DECOMPOSITION OF MOUNTAINS, THE FORMATION OF SOILS, AND ALLUVIAL PRODUCTS.

Proofs of the diminution of Mountains.—Elementary agency.—Final causes.—Formation of Soils.—Mixture of different Earths necessary to form good Soil.—Effects of Lime.—Alluvial depositions from Alpine Countries and Secondary Rocks.—Peat Moors, and Subterranean Forests.

THE diminution of rocks and mountains is constantly taking place by the incessant operation of the elements, until the loftiest eminences are reduced and covered with soil and vegetables, which protect them from further decay. Instances have occurred of whole mountains suddenly falling down and burying the inhabitants of the vales below under their ruins. In the Alps the process of disintegration is rapidly going on; but such is the immensity of these enormous mountains, that ages pass away before any diminution of their bulk is perceived.

According to the account of Patrin, who

had travelled in Northern Asia, the whole of that country is covered to the depth of many hundred feet by innumerable beds of micaceous and argillaceous sand, washed down by inundations from the high range of mountains in the interior of Asia, and carried as far as Siberia. The deserts of Arabia are also covered with alluvial depositions. C. Lukie, Esq. informs me, that between Hit and Tahiba the soil is composed of sand and gravel, on which may be seen small volute and bivalve shells; but the sand is not loose like that in the deserts of Libya.

That the mountains of our island have once been much higher than at present, is evident to every one who has attentively examined them. The rocky fragments in Borrowdale, the deep ravines made by torrents in the sides of Skiddaw, and the scattered rocks at the foot of Snowdon, offer striking proofs of this. The central parts of England have also once had a greater elevation. The white quartz pebbles spread over the midland counties are the remains of the decomposed hills in Charnwood forest, or of others connected with them, which are now worn down. Beacon Hill, one of the highest points of this range, I ascertained by trigonometrical admeasurement, does not rise more than seven hundred and sixty feet above the surrounding country; but all these hills are evidently the remains of a more lofty and extended chain of mountains. Large blocks of white quartz lie upon their summits, which once formed veins intersecting higher rocks; this quartz, being harder, has remained after the other parts were worn down. Veins filled with similar quartz may be traced near the places where these blocks lie.

Besides the destructive effects of mountain torrents so sudden and impetuous in alpine countries, there is another powerful agent in nature that can rend the hardest rocks, and to which mountains that contain much metallic matter are particularly exposed,—this is lightning. The antients, whose descriptions of external nature were almost always correct, have represented the destruction of rocks and mountains as a characteristic phænomenon attending thunder-storms. In the sublime description of a storm in the first Georgic, Virgil refers to the rending of rocks as one of the common effects of lightning.

"——————— ille flagranti
Aut Atho, aut Rhodopen, aut alta Ceraunia telo
Disjecit."

Jove's forked bolt pursues its rapid course,
And rocks and mountains rends with matchless force.

Were the effects of this powerful agent more attended to, perhaps many anomalous appearances in the mineral kingdom might admit of an easy explanation.

It is, however, to the more constant operation of moisture and change of temperature that the disintegration of rocks and mountains may be principally attributed; but no well authenticated observations have yet been made to determine the extent of these effects.

It has been vaguely stated that the height of the Pyrennees is diminishing one foot in a century: hence it was calculated that more than a million years would be required to level the rocky boundary which separates France and Spain.

There are indeed agents in nature,—earthquakes, volcanoes, and perhaps central subterranean fire,—that can entomb whole continents in the ocean, and raise mountains from the watery abyss in a single night. Evident indications exist that such causes have operated extensively on the surface of our planet; but the periods of time in which they are destined to succeed each other, remain beyond the power of human sagacity to determine. By the slow but constant destruction of rocks and mountains new and productive soils are formed to renovate the surface of the globe, and prepare it for the support of animal life: this appears to be the final cause for which the world was created, and to which all terrestrial changes ultimately refer. It has been justly observed by Dr. Paley and others, that in the peculiar conformation of the teeth in graminivorous animals, and in the production of grasses which serve them for food, we may trace evident marks of relation, and of a designing intelligent cause: with equal reason must we admit that the destruction of mountains and the formation of soils for the support of the vegetable tribes are provided for by the same cause, and are part of a regular series of operations in the œconomy of nature: hence also we may infer that those grand revolutions of the globe by which new mountains or continents are elevated from the deep, are part of the same series extending through ages of endless duration, and connecting in one chain all the successive phænomena of the material universe.

By a wise provision of the author of nature it is ordained, that those rocks which decompose rapidly are those which form the most fertile soils, for the quality of soils depends on the nature of the rocks from which they were formed. Granitic and siliceous rocks form barren and sandy soils; argillaceous rocks form stiff clay; and calcareous rocks, when mixt with clays, form marle; but when uncovered by other strata they support a short but nutritious vegetation. For the formation of productive soils, an intermixture of the three earths, clay, sand, and lime, is absolutely necessary. The oxyd of iron appears also to be a requisite ingredient. The proportion necessary for the formation of good soil depends much on the nature of the climate, but more on the quality of the sub-soil, and its power of retaining or absorbing moisture. This alone may make a soil barren, which upon different sub-soil would be exceedingly productive. When this is the case, drainage or irrigation offers the only means of permanent improvement.

Different vegetables also require different admixtures of earth. They require it, first, because it is necessary to their growth that the soil should be sufficiently stiff and deep to keep them firm in their place; and also that it should not be too stiff to permit the expansion and growth of their roots: and, lastly, that it should supply them with a constant quantity of water, neither too abundant nor deficient. Hence we may learn why different degrees of tenacity, depth, and power of retaining or absorbing moisture, are required in soils for different kinds of plants. Thus, in uncultivated countries, we find that certain vegetables affect particular situations in which they flourish spontaneously and exclusively; and it is only by imitating nature, and profiting by the instruction she affords, that we can hope to obtain advantageous results, or acquire certain fixt principles to guide us in our attempts to bring barren lands into a state of profitable cultivation. When rocks contain in their composition a due proportion of silex, clay, and lime, they furnish soils whose fertility may be said to be permanent.

The most fertile districts in England were made so by nature; their original fertility was independent of human operation.

Some small portion of the earths and alkalies is found by chemical analysis in plants: but it would be contrary to fact and analogy to suppose that the earths in a concrete state form any part of the food of plants. The earths and alkalies which they contain are in all probability formed by the process of vegetation from mere simple elements, for it is now ascertained that the earths and alkalies are compound substances.

The principal elements found in plants are hydrogen, carbon, and oxygen; and by recent experiments of Gay Lussac and Thenard* it appears that the hydrogen and oxygen in starch, gum, vegetable oils, and sugar, exist in precisely the same proportion that forms water. Carbon, the other principal elementary substance found in plants, exists both in water and the atmosphere. Water and the atmosphere contain in themselves, or in solution, all the elements necessary for the support and growth of vegetables. But most soils are either too wet or too dry, too loose or too adhesive, to admit plants to extract these elements in the proportions necessary for their growth. Manures supply this deficiency by furnishing in great abundance the hydrogen, carbon, or azote, which they may require. In proportion as soils possess a due degree of tenacity, and power of retaining or absorbing heat and moisture, the necessity for a supply of manure is diminished, and in some instances the earths are so fortunately combined as to render all supply of artificial manure unnecessary. He who possesses on his estate the three earths, clay, sand, and lime, of a good quality, with facilities for drainage or irrigation, has all the materials for permanent improvement; the grand desiderata in agriculture being to render wet lands dry, to supply dry lands with sufficient moisture, to make adhesive soils loose, and loose soils sufficiently adhesive.

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* Recherches Physico chimiques.

The intermixture of soils, where one kind of earth is either redundant or deficient, is practised in some countries with great advantage. Part of Lancashire is situated on the red sand rock described in the sixth chapter. This rock, being principally composed of siliceous earth and the oxyd of iron, forms of itself very unproductive land: but fortunately in many situations it contains detached beds of calcareous marle near the surface. By an intermixture of this marle with the soil, it is converted into fertile land, and the necessity for manure is superseded. The effect of a good marle applied liberally to this land, lasts for more than twenty years. In some lands, a mixture of light marle which contains scarcely a trace of calcareous earth is found of great service. The good effect of this appears to depend on its giving to the sandy soil a sufficient degree of tenacity. On the contrary, in stiff clay soils, where lime is at a great distance, the land might frequently be improved by an intermixture with siliceous sand. A proper knowledge of the quality of the sub-soil and the position of the sub-strata is necessary to ascertain the capability of improvement which land may possess. It may frequently happen that a valuable stratum of marle or stone which lies at a great depth in one situation, may rise near the surface in an adjoining part of the estate, and might be procured with little expense.

Lime is the only earth which has been generally used to intermix with soils, and has been considered as a manure; but its operation as such is very imperfectly understood. Burnt lime, when caustic, destroys undecomposed vegetable matter, and reduces it to mould,—so far its use is intelligible. It combines also with vegetable or mineral acids in the soil which might be injurious to vegetation,—here its operation is likewise intelligible; but if we assert that when burnt lime has absorbed carbonic acid and become mild, it gives out its carbon again to the roots of plants, we assume a fact which we have neither experiments nor analogies to support. The utility of lime in decomposing vegetable matter and neutralizing acids is obvious; but its other uses are not so evident, except we admit that it acts mechanically on the soil, and renders the clay or sand with which it is intermixt better suited to the proper expansion of the roots, and more disposed to modify the power of retaining or absorbing the requisite degree of heat and moisture which particular vegetables may demand.

Where earths are properly intermixt, instances are known of land producing a succession of good crops for many years without fallowing or manure. On the summit of Breedon Hill, in Leicestershire, I have seen a luxuriant crop of barley growing on land that had borne a succession of twenty preceding crops without manuring. This is more deserving notice, being in an exposed and elevated situation, and upon the very hill of magnesian lime which has been so frequently referred to by chemical writers as peculiarly unfavourable to vegetation. The lime-stone of this hill contains above 20 per cent. of magnesia*.

The temperature requisite for the growth of plants is influenced by the power of different soils to absorb and retain heat from the solar rays, which depends much on their moisture and tenacity. "It is a well known fact, that the vegetation of perennial grasses in the spring is at least a fortnight sooner on lime-stone and sandy soils, if not extremely barren, than on clayey or even in deep rich soils: it is equally true, but perhaps not so well known, that the difference is more than reversed in the autumn."—(Observations on Mildew, by J. Egremont, Esq.) This effect Mr. E. ascribes with much probability to the rich or clayey soils absorbing heat slowly, and parting with it again more reluctantly than the calcareous soils, owing to the greater quantity of moisture in the clay, which is an imperfect conductor of heat.

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* The magnesian lime acts more powerfully in destroying undecomposed vegetable matter than common lime, and its effects on land are more durable: hence it is in reality of greater value in agriculture, as a much smaller quantity will answer the same purpose.

Calcareous soils might frequently be much improved by a mixture of clay, sand, or gravel, which in many situations is practicable with little expense, and would well reward the labour of the experimental agriculturist.

Alluvial ground formed from the materials of decomposed rocks, will differ according to the nature of the rocks in different districts.

In mountainous countries, alluvial grounds are principally composed of fragments of rocks worn by attrition, and of pebbles and sand. Metallic ores, which are very hard, or indestructible, are also found in the alluvial depositions of primary and transition rocks. Tin-stone, or ore of tin, is found in the form of rounded pebbles, in the banks and sands of the rivulets in Cornwall, and under the sand on the sea shore. There can scarcely be a doubt that this ore once formed veins intersecting mountains that are decomposed and worn down. Small pieces of gold have occasionally been found in similar situations, which, as well as the gold in the sands of rivers in different parts of the world, had in all probability a similar origin. The diamond, and other precious stones which occur in alluvial depositions, were also probably brought there, from decomposed rocks, by inundations and mountain torrents.

Whether the immeasurable tracts of loose sand in Africa were formed from the destruction of siliceous mountains, or by other processes, cannot be determined. During volcanic eruptions, an extent of some hundred square miles has frequently been covered with volcanic sand; but this is of a dark gray colour, contains a considerable portion of argillaceous earth, and becomes consolidated by moisture.

It is observed that the boulders and pebbles from mountainous districts decrease in size as they advance further into the plains; which is a proof, if any were wanting, that they have been driven by water to their present situations; the smallest yielding to the least impulsive force would be removed to the greatest distance from the mountains. Gravel is evidently an alluvial production, and we may observe the process of its formation on the sea shore, near precipitous cliffs, where the angular fragments that fall down are incessantly rolled to and fro by the action of the tides and formed into round pebbles. The chalk cliffs on the southern coast of England offer an illustration of this; they are frequently falling down, and the imbedded flints, that are broken and urged alternately backward and forward by the tides, may be distinctly heard rattling and grinding on each other after each retiring wave. Flat fragments of tiles left in the same situation are soon rounded by constant attrition. The small sand on the sea shore and in gravel is formed by a further process of comminution. On the eastern shore, particularly near Scarborough, beautiful pebbles of agate, chalcedony and carnelian, are thrown upon the sands, after a high tide: no similar stones exist in the rocks on that part of the coast. There are, however, chalcedony and agates in the rocks of porphyry and amygdaloid forming the Cheviot Hills in Northumberland,

land, which are washed down by mountain torrents, and carried into the streams that flow from thence into the sea. Some of these pebbles may be brought from those hills, and others from the more remote mountains of Scotland.

Extensive tracts of cultivated ground are sometimes converted into sandy deserts; the process is taking place at present, and has been well described by Cuvier. During very high winds the sand on the sea shore is driven inland, covering the ground to a certain distance, and leaving an elevated ridge at the further boundary; succeeding winds blow this sand forward, and at the same time bring fresh sand from the shore to supply its place.

In the sixth volume of the Transactions of the Irish Academy, an account is given of the encroachment of the sand over some parts of Ireland. Trees, houses, and even villages have been covered or surrounded during the last century. The roofs still rising above the waste attest the period and the progress of desolation.

The loose sands of Libya are thus spreading over the plains that border the Nile, and burying the monuments of art and the remembrance of former cultivation. From a similar cause the country immediately round Palmyra, that once supplied a crowded population with food, now scarcely affords a few withered plants to the camel of the wandering Arab. By planting and irrigation man can fix limits to the moving wastes of sand; but despotic power, more destructive than the winds of the desert, unnerves the arm of industry, and, dashing the cup of enjoyment to the ground, consigns flourishing and fertile districts to eternal sterility and solitude.

Sandy tracts are also frequently formed by the disintegration of a thick sand-stone stratum rising to the surface, and extending over a considerable extent of country.

We are not to conclude that all beds of sand and clay are formed by the destruction of other rocks. They are sometimes as much an original part of the globe, as any of the secondary strata. The particles of sand in some situations have the regular crystalline forms of rock crystals with the angles sharply defined; which could not have been the case had such sand been formed from the debris of sand-stone worn down by the action of water. A bed of sand of this kind at Neuilly in France is described by De Lille as being composed of transparent rock crystals, which when examined with a lens were perfect hexahedral prisms.

In some sand-stones the particles of quartz are too crystalline and angular to admit the belief that they were formed from the debris of former rocks, unless we were to suppose with some geologists that such strata had been in a melted or confluent state, which allowed the particles to acquire a crystalline arrangement. In other sand-stones the fragments and particles are worn by attrition, and have been cemented by clay and oxyd of iron. When the fragments are large and smooth, the mass is called pudding-stone.

Breccia, or pudding-stone, consists of fragments or of pebbles agglutinated in a hard cement formed by the consolidation of the loose materials in which they are imbedded; but some breccias appear to have a different formation, and cannot be classed with alluvial products.

Earthy particles, deposited and agglutinated, form beds of tufa. Calcareous tufas occur in the neighbourhood of lime-stone mountains, in which the fragments of limestone are frequently imbedded.

Peat is one of the most important productions of alluvial ground; it may be regarded as belonging more properly to the vegetable than the mineral kingdom. Peat formerly covered extensive tracts in England, but is disappearing before the genius of agricultural improvement, which has no where produced more important effects than in the conversion of the black and barren peat moors of the northern counties into valuable land covered with luxuriant herbage, and depastured by numerous flocks. The following description of the peat moors in Scotland, by Mr. Jameson, is an accurate picture of the remaining peat moors in the mountainous parts of Yorkshire and the adjoining counties.

"In describing the general appearance of a peat moor, we may conceive an almost entire flat of several miles extent, of a brown colour, here and there marked with tufts of heather, which have taken root, owing to the more complete decomposition of the surface peat; no tree or shrub is to be seen; not a spot of grass to relieve the eye in wandering over this dreary scene. A nearer examination discovers a wet spongy surface, passable only in the driest seasons, or when all nature is locked in frost. The surface is frequently covered with a slimy black-coloured substance, which is the peat earth so mixt with water as to render the moss only passable by leaping from one tuft of heather to another. Sometimes, however, the surface of peat mosses has a different aspect, owing to the greater abundance of heath and other vegetables, as the schœni, scirpi, eriophora, &c: but this is principally the case with some kinds of what are called muirlands, which contain but little peat, being nearly composed of the interwoven roots of living vegetables. Quick moss (as it is called) is a substance of a more or less brown colour, forms a kneadable compound, and when good, cuts freely and clean with the spade; but when it resists the spade by a degree of elasticity, it is found to be less compact when dried, and is of an inferior quality. The best kinds burn with a clear bright flame, leaving light-coloured ashes; but the more indifferent kinds in burning often emit a disagreeable smell, and leave a heavy red-coloured kind of ashes. In digging the peat, we observe that when first taken from the pit it almost immediately changes its colour, which becomes more or less a deep brown or black, and the peat matter becomes much altered, being incapable of forming a kneadable paste with water. When dry and reduced to powder, as it is often by the action of the weather, it forms a blackish-coloured powdery matter, capable of supporting vegetation when calcareous earth is added.

"Peat is found in various situations, often in valleys or plains, where it forms very extensive deep beds, from three to forty feet deep, as those in Aberdeenshire: it also occurs upon the sides of mountains; but even there it is generally in a horizontal situation. The tops of mountains, upwards of 2,000 feet high, in the Highlands of Scotland, are covered with peat of an excellent kind.

"In Germany it is also found at very great heights; thus, the Blogsberg, a high mountain in Lower Saxony, and the Brohen, the highest mountain of the Hartz, are also covered with peat. It is also found in situations nearly upon a level with the sea: thus, the great moss of Cree in Galloway lies close upon the sea, on a bed of clay, little higher than the flood marks at spring tides*."

A peat moor below the level of the sea extends along the eastern coast of Lincolnshire and Yorkshire. Under the surface there is a forest of trees considerably below the present high water mark. From the stumps and roots of trees that may be discovered at low water, it is supposed that the ground has sunk down on this coast. This forest appears to extend under the sea. A similar subterranean forest appears to extend under the sea on the Lancashire coast between Liverpool and Preston, and a peat moor exists at a very low level on that side of the county.

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* Mineralogy of the Shetland Islands.

It is deserving notice that the remains of large quadrupeds, found in alluvial ground, are seldom of animals that exist in the countries where they occur, and many of them are of extinct species. The remains have frequently undergone but little change, and preserve the constituent parts of common bone.

Except organic remains and the particles of metallic matter found in certain sands near alpine districts, alluvial ground may be considered as more interesting to the agriculturist than the geologist. But even here some knowledge of geology is of considerable practical importance in the improvement of land. An acquaintance with the nature, position, and inclination of the sub-soil and sub-strata is absolutely necessary in order to carry on any extensive system of drainage in the most efficacious and least expensive manner. Mr. Elkington, who first directed the attention of landed proprietors to this subject, and explained the principles on which he proceeded, rendered a most essential service to agriculture: his merits were scantily rewarded, but he may be justly ranked among the first benefactors of his country.

CHAP-

CHAPTER XII.

MINERAL DYKES

Mineral Dykes inters
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Remarkable Dykes
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Veins.—Pipe Vein
Opinions respecting
Analogous Facts ill
which Metallic Ore
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clay, are called dykes or faults. When they contain metallic ores they are generally called veins.

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Dykes are frequently filled with basalt, green-stone, or porphyry. Those which intersect coal fields have been already noticed, page 181, and their effects on the contiguous strata described. The more usual substances found in these dykes are whin-stone (basalt) or clay.

The thickness of dykes varies from a few inches to twenty or thirty feet or yards; in some instances they exceed three hundred feet. The extent to which they stretch across a country has seldom been explored beyond the mining districts, where a knowledge of them is important on account of the disturbances in the strata which they occasion.

The dislocations of the coal strata by faults are represented plate II. fig. 2 and 3. C. C. and D. D. Dykes or faults generally decline a little from a vertical position, and, as before stated, the depth to which they descend is unknown.

The strata are almost always thrown down on one side of a dyke, and elevated on the other; but the dislocation is not proportioned to the width. There is a fault extending from Whitley in Northumberland to Green-side and Sandgate in Durham, which has thrown down the strata on the north side one hundred and eighty yards; this is a comparatively narrow fissure filled with clay. The great dyke in the same county, before mentioned in the fifth chapter, which is seventeen yards wide, has only produced a dislocation of twelve yards.

The whole series of strata which have been raised on one side of a fault have sometimes entirely disappeared.

The stone with which dykes are filled is frequently harder than the rocks which they intersect, and remains after the latter are decomposed on the surface, forming immense walls of stone: such are met with in the counties of Northumberland and Durham, and on the western coast of Scotland; where the violence of the Atlantic Ocean has torn away the surrounding rock. They may be seen extending into the sea.

When dykes are of considerable thickness, it is observed that the mineral substances which they contain vary in hardness; sometimes the central parts and sometimes the sides are harder or softer than the other, being divided by seams or partings. This may be distinctly seen at Coaly Hill near Newcastle upon Tyne, where a large basalt or whin dyke cuts through the coal strata, and rises to the surface. The stone being hard is quarried for the roads along a line of several hundred yards, forming a deep trench sufficiently wide to admit a cart road through the quarry between the walls or sides of the dyke.

The basalt of the dyke is intersected by fissures, and divided into variously shaped masses. In one part of the dyke it appears to graduate into an indurated ferruginous clay, which is in some places divided into minute well-defined pentagonal prisms. This dyke has produced the same effect of charring the coal described in the fifth chapter, page 148. To use the language of the workman who was quarrying the stone when I visited the place, " it had burned the coal wherever it had touched it." This dyke extends from the sea to the western side of the county of Northumberland; its termination in that direction is unknown.

Columnar basaltic rocks are sometimes intersected by dykes of basalt; and it is remarked that the basalt in these dykes has also a columnar structure, being composed of prisms, which are laid horizontally, or in a contrary direction to the position of the columns in the range. Those who suppose that basaltic rocks had an igneous origin consider this circumstance as favourable to the hypothesis. The melted basalt ejected into the dyke would first begin to cool and crystallize where it was in contact with the rock on each side of it: hence the diminution of temperature, acting laterally, has given to these prisms an horizontal position. On the contrary, the columns in the range were formed by a diminution of temperature, commencing in a vertical direction, which must have been the case whether they were formed on land or under the ocean.

If dykes have been formed by the expansive force of subterranean heat breaking the surface, and forcing melted matter into the fissure, we may expect to find rocks and strata much torn and dislocated in their vicinity; and such is generally the case. Also where a mountain or rock rises abruptly, and the beds or strata are thrown into opposite directions, we may presume the existence of a dyke or fault, which has produced the irregularity we observe. More frequently, however, a series of fissures or faults of greater or less magnitude may be found near the declivities of very abrupt mountains: thus, on the western side of the mountainous range which separates Yorkshire from Lancashire and Cheshire, the ground near the declivities of these mountains is so much broken by a succession of faults, that it renders mining operations exceedingly uncertain and difficult. In some instances the precipitous sides of mountains or rocks have been formed by the action of currents, when the relative level of the sea has been much higher than at present.

The longest mineral dyke that has been traced in England may be called the Cleveland Basalt Dyke: it extends from the western side of Durham to Bewick in Yorkshire; it crosses the river Tees at this place, and proceeds in a waving line through the Cleveland Hills in the East Riding of Yorkshire to the sea between Scarborough and Whitby. It rises to the surface, and is quarried in many parts of its course for stone to lay upon the roads. From Berwick on the Tees it may be traced in an easterly direction, near the villages of Stanton, Newby, Nunthorp and Ayton. At Langbath ridge a quarry is worked in it; it passes south of the remarkable hill called Roseberry Toppin, near Stokesly, and from thence by Lansdale to Kildale; it may be seen on the surface nearly all the way in the above track. From Kildale it passes to Denbigh Dale end, and through the village of Egton bridge, and hence over Leace ridge through Gothland, crossing the turnpike road from Whitby to Pickering near the seven mile stone, at a place called Sillow Cross on a high moor. I examined it at this place, where it is quarried for the roads, and is about ten yards wide. From hence it may be traced to Blea Hill near Harwood Dale, in a line towards the sea, near which it is covered with alluvial soil; but there can be no doubt that it extends into the German ocean. It is a dark grayish brown basalt which turns brown on exposure to the atmosphere; it is the principal material for mending the roads in the district called Cleveland. I am indebted to Mr. Bird of Whitby for an account of the situations where it may be seen on the surface. He has traced it through Yorkshire and Durham; in the latter county it cuts through the coal strata. The dyke described as extending to Cockfield and charring the coal on each side of it, is in fact a continuation of this great dyke. According to Mr. Bird, it crosses the river Tees again, near Tees Force, and, expanding, forms the great mass of basalt on the western extremity of Durham, taking the columnar form in various parts, particularly at High Cup, a deep circular excavation on the side of Cross Fiell. The specimens of the stone shown me by Mr. Bird from this district, are more crystalline and less homogeneous than that in Cleveland, being that variety called green-stone, consisting of hornblende and felspar. The course of this dyke is marked in the Geological Map of England, plate IV. By consulting the large maps of England the course may be distinctly traced: drawing a line in the direction from Cockfield in the county of Durham to Bewick on the Tees, and extending it east and west, it will pass near all the places above mentioned.

There is another remarkable dyke, which

crosses the western extremity of Durham from Allen Heads to Burtreeford on the Tees hence, called the Burtreeford dyke. It throws down the strata on the west side of it one hundred and sixty yards. As this dyke runs nearly north and south, it must cross the great dyke north of Burtreeford. The phænomena attending this junction will form an interesting subject for future investigation*. The

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* Mr. Farey, in his Survey of Derbyshire, has described a great fault commencing near Nottingham, and extending in a westerly direction by Ashburn, and from thence into Cheshire, where it turns northward, and extends to Lancashire or Yorkshire. This he has called the great Derbyshire Fault, and has traced its course on a map of that part of England.—*Farey's Survey of Derbyshire,* vol. i. 97.

I confess I could discover no indications of the existence of this fault, having attentively examined part of the country through which it is said to range; nor has Mr. Farey stated any particulars respecting its thickness, or the mineral substances with which it is filled. So far from any dislocation of the strata being perceptible, the beds of the sand-rock at Nottingham are nearly horizontally divided by seams which contain rounded pebbles: the strata at Ruddington hills on the opposite side of the vale are but little inclined; the strata in the vale are nearly horizontal, wherever wells or excavations have been made. No disturbing force appears to have changed their position

The Cleveland dyke has been traced in a direct line more than seventy miles. A circumstance attending this and other extensive dykes, which has not, I believe, been hitherto regarded by geologists, completely invalidates the theory, that dykes were originally open fissures formed by the drying or shrinking in of the rocks. This dyke in its course intersects very different formations, viz. the metalliferous lime-stone, the coal district, and the hills of aluminous schistus. The different organic remains in these formations, as well as their position, prove that they were consolidated at distant periods of time. Indeed

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sition since their formation. Had a fault existed which rent the island from Nottingham to Macclesfield in Cheshire, it would have left no dubious marks of its existence in every part of its course.

Though I differ from Mr. Farey in some of his opinions respecting the geology of Derbyshire, I feel great pleasure in bearing my testimony to the general accuracy of his statements. His Survey of Derbyshire contains much valuable information, and ought to be in the library of every landed proprietor in that part of England. Had the description of facts been kept more distinct from the conjectures, and the lists of mines, &c. been detached from the narrative, it would have been more generally interesting, and its merits better appretiated.

deed the geologists who maintain that dykes were formed as before described, are ready to admit the distant æras of these formations. The metalliferous lime-stone and the lower strata must have been completely consolidated long before the upper strata were deposited, and the causes which might dispose the upper strata to shrink in, cannot be supposed to act on the lower rocks. It is also to be remarked that in the lower rocks, situated to the west, the breadth of this dyke is more than twenty yards; but at Sillow Cross, where I measured it, it is not more than ten yards. This dyke must therefore become wider as it descends. It must also have been filled at the time of its formation, otherwise it would have contained numerous fragments of the rocks which it intersects. As it passes through the lime-stone on the west, I am informed that the latter is more crystalline in the vicinity of the dyke. Its effects in charring the coal, and the formation of sulphur on the contiguous strata before described, point to subterranean fire as the original cause of its formation, and as the source whence the basalt which fills it was supplied. When we also consider the close resemblance between basalt and compact lava, both in appearance and constituent elements, I think we can scarcely hesitate in admitting that this great dyke was formed by an expansive force operating from below, which opened a chasm in the surface of the earth, and ejected the contents in a state of fusion. Nor will it lessen the probability of this mode of formation, that we have actual instances of similar phænomena taking place in our own times, both in Europe and America.

On the 12th of June 1794, after violent shocks of an earthquake had been felt at Naples and in the neighbourhood, a vast rent was made on the western side of the base of Vesuvius two thousand three hundred and seventy-five feet in length and two hundred and thirty-seven feet in breadth, through which lava was thrown up to the surface. This lava when cooled formed a wall of stone intersecting the former beds of lava, and constituting a real dyke. It has a dark gray colour, and is in some parts so compact as to resemble horn-stone; it strikes fire with steel, and like many basaltic rocks it yields an earthy smell when breathed upon.

The manner in which dykes hold up the

water was before stated. From this circumstance it frequently happens that numerous springs make their appearance along the course of the dyke, and hence it may sometimes be detected where no other indication of it is visible at the surface.

Veins of quartz, and also of slate and granite, and various earthy minerals, without any metallic ores, frequently intersect granitic and schistose rocks. These are closely united with the rock, and appear to graduate into it: hence we can scarcely doubt that they were either formed at the same time, and are what have been called cotemporaneous veins; or that the rock and the substance of the vein have been in a confluent state at the same time, whatever may have been the process by which it was effected.

The principal repositories of metallic ores are also called veins. Rake veins or perpendicular veins resemble mineral dykes in position, but not in their contents. Dykes intersect every kind of rock, but metallic veins are principally confined to primary and transition or lower secondary rocks.

Metallic veins are often separated from the rocks they intersect, by a thin wall or lining of mineral substances distinct from the rock, and sometimes also by a layer of clay on each side of the vein. The same substance which forms the outer coat of the vein is also frequently intermixt with the ore, or forms layers alternating with it: this is called the matrix, gangue, or vein-stone. It appears as if the ore and the vein-stone had been formed over each other, on the sides of the vein, at different times, till they met and filled up the fissure.

Sometimes the ore extends in a compact mass from one side of the vein to the other. Not unfrequently there are hollow spaces in veins, called druses, which are lined with crystals. In these cavities the most beautiful and regular crystalline forms are obtained. Metallic veins often divide and unite again, and sometimes they separate into a number of smaller branches called strings. To what depth metallic veins descend is not known, nor is it ascertained whether they generally grow wider or narrower in their descent. The opinions of miners on this subject are so various, that it may fairly be inferred that they differ in this respect in different situations. No instances I believe have occured of a vein being worked out in depth, though it often grows too poor to repay the labour of working deeper: more frequently the further descent of the miner is stopped by the difficulty of removing the water. Veins are seldom rich in ore near the surface, but increase in richness as they descend, and at greater depths become poorer again. When Pryce wrote the Mineralogy of Cornwall, it was believed that the richest state of a mine for copper in that county was from eighty to one hundred yards deep, and for tin from forty to one hundred and twenty yards. This account by no means agrees with the present state of the Cornish mines. Copper and tin are procured in considerable quantities at the depth of four hundred and fifty-six yards in the Dolcoath mine. The Ecton copper mine in Staffordshire is now worked at the depth of four hundred and seventy-two yards: it is the deepest mine in England. The deepest mine that has been worked in Europe, or in any part of the world, is one at Truttenberg in Bohemia, which is one thousand yards below the surface.

Metallic veins frequently contain different ores at various depths. Iron ore, copper ore, cobalt ore, and silver ore succeed each other in some of the mines in Saxony.

In France there are mines which contain copper ore in the lowest part, silver ore above, and over that iron ore.

In Cornwall, blende, a sulphuret of zinc, frequently abounds in the upper part of veins that become rich in copper as they descend, the blende rarely continuing to any considerable depth. In the same district tin is also commonly found at a small depth in veins which afterwards prove rich in copper. "Among other instances that might be quoted, are the two deep extensive copper mines called Huel Unity and Cook's Kitchen, both of which were worked for tin at first. In both the tin was soon extracted; but it should be noted as an uncommon circumstance, that in the latter mine, after working to the depth of one hundred and eighty fathoms, first through tin and afterwards through copper, tin was found again, and has continued down to its present depth of two hundred and ten fathoms from the surface. It ought however to be added, that some portion of tin was found in different parts of the vein, which may therefore be said to have prevailed more or less from the surface to the present workings*."

The thickness of veins, and the quantity and quality of the ore they contain, vary in every mine. Some veins are only a few inches wide; others are several feet, and sometimes several yards, in width. Veins are often narrow in one part, and swell out in another. The vein at the Dolcoath mine in Cornwall varies from two or three feet to forty feet, and in some places it contracts to little more than six inches. The vein-stone is quartz, in which are imbedded masses called bunches of copper pyrites, consisting of copper united with sulphur.

Beside rake veins there are other mineral repositories, called flat veins or flat works, and pipe veins. In some instances a rake vein declines from its regular inclination, and has taken the direction of the beds or strata for a greater or less extent, and then resumes its former inclination. In other instances the cavities between beds or strata are filled with metallic ores, lying between an upper and lower stratum, like a seam of coal, and are subject to similar dislocations: but these are not regular strata; they may frequently be traced to a perpendicular or rake vein, from which they appear to be lateral expansions; see plate VII. fig. 2; though there is generally what is called a rider or mass of mineral matter between the ore of very strong rake veins, and that in the flat veins at the place of junction. Though flat veins run parallel between the strata, they frequently open into large cavities filled with ore and vein-stone: these cavities close again by the contracting, or what the miners call twitching of the sides, by which the ore is nearly or totally excluded. Such expansions and twitchings are also common to rake veins, and are represented at *C C*, plate II. fig. 4.

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* Transactions of the Geological Society, vol. 2.

The blue john or fluor spar mine near Castleton is of this kind. The vein which contains this spar is separated from the limestone rock by a lining of cawk or sulphat of barytes, and by a thin layer of unctuous clay; it swells out into large cavities, which contract again and entirely exclude the ore, leaving nothing but the lining of the vein to conduct the miner to another repository of the spar. The crystallizations and mineral incrustations on the roof and sides of the natural caverns which are passed through in this mine, far exceed in beauty those of any other cavern in England; and were the descriptions of the grotto of Antiparos translated into the simple language of truth, I am inclined to believe it would be found inferior in magnificence and splendour of mineral decoration to the natural caverns in the fluor mine. This mine is rarely visited by travellers: the descent is safe, but the roof being low in some parts it is rather difficult of access.

When a flat vein runs parallel with the beds or strata of a mountain to a considerable extent, it has frequently been confounded with the regular beds of the mountain, and supposed to be of cotemporaneous origin, and a distinct formation, from veins. Iron, which is universally disseminated through the mineral kingdom, most commonly occurs in beds forming an original part of rocks: but, besides iron and manganese, it may be doubted whether what are called metallic beds are not properly flat veins, which have taken the same direction with the regular seams or strata of the rock. I am not aware of any regular metallic beds in our island, which may not be considered as flat veins, except beds of iron ore or manganese, and perhaps of bituminous marle-slate impregnated with copper.

The pipe vein may be described as a tubular mass of ore and vein-stone generally descending in the direction of the beds, and widening and contracting in its course. In reality, the pipe vein is a variety of the flat vein having the sides closed or twitched in, so as to from a tube or cavity of irregular shape and of very limited extent along the line of bearing, but descending to a great depth. Masses of ore are occasionally found detached, without any apparent connection with the surface or other metallic veins. Ores are also sometimes disseminated through rocks, of which they appear to form an original constituent part.

One metallic vein often crosses or cuts through another and displaces it: in such instances it is evident that the vein which is cut through must be more antient than that which intersects it. This observation respecting the relative ages of veins was first made by Mr. Pryce in his Mineralogia Cornubiensis. The different position of veins is represented in plate II. fig. 4, where *a a* is a vein intersecting a rock; it divides in part of its course and unites again, and finally branches off into small strings. In many instances these strings lead to a further continuation of the vein; perhaps this would be found to be the case in all, were the workings carried on in the same direction. *b b* is another vein which cuts through the former, and has thrown the lower part of the vein *a* out of its course. Sometimes one vein passes through another without changing its direction. When one vein crosses another which has an opposite inclination, it is observed that they often become poorer; but when two veins which have the same general inclination unite, they are most frequently very rich in ore at the junction; (plate VII. fig. 4. *a* and *b*) and when a number of veins cross each other at one place, they sometimes form a cone or mass of ore of prodigious size, widening as it descends. Such are called accumulated veins. They occur in the mining district of Durham and Northumberland in the metalliferous lime-stone.

The excavation formed when the ore is worked out resembles in shape the inside of a large glass furnace.

The direction of rake veins is not very regular. In England the principal veins generally run nearly east and west, and north-east and south-west; but have frequently undulations and deviations from a straight line: the most powerful veins are more regular in their course than smaller ones. Where two veins in the same district have the same direction, or run parallel, it is observed that their contents are similar; but where they run in different directions the contents vary. Molina in his interesting History of Chili mentions a vein of silver at Uspalata, in the Andes, which is nine feet in thickness throughout its whole extent, and has been traced ninety miles. Smaller veins branch off from each side of it, and penetrate the neighbouring mountains to the distance of thirty miles. It is believed that this vein stretches to the distance of three hundred miles. A vein called the Tidswell Rake, in Derbyshire, extends some miles east and west; it is worked from the surface, and may be seen near the road side between Great Hucklow and Tidswell.

well. It is lost at its two extremities by the lime rock which it intersects dipping under other rocks; but in the opinion of miners who have worked in North Wales, the same vein rises again in the lime rocks of that district.

In Cornwall and Devonshire, and in the mines of Northumberland and Durham, the principal metallic veins range nearly east and west. In the former counties they are called *lodes*, in the latter *right running veins*. The north and south veins which intersect them are called cross courses, these are seldom productive of ore. In Cornwall silver and cobalt have been found in some of the cross courses. And in Northumberland and Durham the cross courses contain ore near their junction with the principal veins. In Cornwall the cross courses displace the east and west veins; the displacement is only a few inches in some veins, in others it is several fathoms. On Alston Moor in Cumberland a large cross course called Old Carr's cross vein cuts through two veins called Goodham Gill vein and Grass Field hill vein, and has thrown them aside about fifteen or twenty fathom. When the cross course intersects the east and west veins at right angles, the displacement is generally less than when it strikes it in an oblique direction. This effect will be more clearly conceived by referring to plate VII. fig. 3, which is supposed to represent a ground plan of the principal veins intersected by a cross course.

Particular metallic ores are peculiar to certain rocks. Thus, tin-ore occurs in granite and some kinds of slate, but has never been found in lime-stone. Certain ores are also associated together: thus lead and zinc almost always occur in the same vein, but in different proportions. Metals are rarely found in a native state, except platina, gold, silver, and copper. They are usually combined with some substance by which they are mineralized, which is either oxygen, sulphur, or an acid; sometimes they are combined with other metals, and form alloys. Different combinations of the same metal exist in one vein. Native copper, sulphuret of copper, carbonate of copper, or malachite, sulphat of copper or blue vitriol, and copper combined with lead and iron, frequently occur together in the same mine.

Galena, a sulphuret of lead, is often associated with white lead ore, or carbonate of lead. The latter, though a rich ore containing seventy per cent. of lead, has no metallic appearance, and was mistaken for cawk and thrown away by the miners in Derbyshire until the year 1803 or 1804. The mines of that county have been worked since the time of the Emperor Adrian, and the quantity of ore which has been wasted during that period must have been immense*.

In what manner metallic veins were filled with ore has greatly divided the opinions of geologists. Dr. Hutton supposes that both dykes and veins were filled with their contents in a state of fusion by injection from below, the expansive force of the melted matter having cracked the surface and opened a passage for its reception. That many dykes were so formed I think probable from circumstances

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* In 1810 few of the working miners could distinguish compact white lead ore from cawk or sulphat of barytes; their specific gravity and appearance are not very different. The following test is of easy application, and will serve to discover the presence of lead. If a small quantity of flower of brimstone, mixt with a little potash or soda, be melted on the point of a knife, in a candle, and applied to the moistened surface of the stone, it will make a black spot if the mineral contain white lead ore.

stances previously stated. Other dykes appear to have been open fissures filled by materials washed from the surface, and contain rounded stones and sometimes undecayed vegetable matter. From a dyke of clay in a coal mine in Yorkshire, two hundred and fifteen feet deep, I have drawn out long vegetable fibres, apparently roots; the woody part of which was unchanged, and burned like the roots of common weeds. Werner supposes all veins and dykes were first produced by the shrinking of the materials of which mountains are composed; and that metallic veins have been filled from above by the ores in a state of solution. This theory has been advanced with much confidence, and warmly supported by many geologists: but I have no hesitation in asserting that it is demonstratively repugnant to facts: indeed, the implicit credit which has been given to Mr. Werner's dogmas on this subject, is one among numerous instances of men of distinguished talents resigning their judgement to authority, and supporting the most absurd propositions when conformable to their favourite hypotheses. If veins were filled by metallic solutions from above, these solutions must have covered the highest mountains over the whole earth; and instead of finding metallic ores in the present confined repositories, they would fill all the cavities and valleys in every part of the world. As this theory supposes likewise that veins were formed at different times, a number of these metallic solutions would succeed each other, and we should find regular strata of ore in all primary and transition rocks; and the quantity formed by these deep seas of metallic matter would be inconceivably great*.

This theory is decidedly invalidated by the following facts. When a metallic vein passes through different kinds of rock, it is generally observed that the quality of the ore varies with that of the rock through which it passes; and even different beds of the same rock are more productive than others, and are called by miners bearing measures. This is the case, in Durham, Derbyshire,

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* Metallic ores may, in some instances, have been formed in fissures which were once open at the top, or veins may have been reopened by a subsequent convulsion. The round pebbles which are sometimes found in veins prove that there must in such instances have been a connection with the surface.

Cornwall, and probably in every mining district in England and Wales.

Not only does the variation in the nature of the rock occasion a change in the quantity or quality of the ore, but the mineral substance or matrix which accompanies ores generally varies in different kinds of rock. Quartz and barytes are more frequent in granite and slate rocks than calcareous spar. In calcareous mountains quartz is more rarely the prevailing matrix. In the counties of Durham and Northumberland, veins pass through siliceous sand-stone, argillaceous shale, and lime-stone. The ore is more abundant in the lime-stone than the sand-stone, and in the shaleprovin cially called plate, ore very rarely if ever occurs. In one mine at Welhope the matrix of the vein, as it passes through the sand-stone, is caulk or the sulphat of barytes; but when it enters the lime-stone it changes to carbonate of barytes in balls having a radiated diverging structure. But what is still more deserving of notice, when the rock on one side of a vein is thrown up or down considerably, so as to bring a stratum of lime-stone opposite a stratum of sand-stone, or when what are called the walls or cheeks of the vein are of two different kinds of stone, (see plate VII. fig. 5.) the vein is never so productive in ore, as when both sides of the vein are of the same kind. This fact alone seems sufficient to invalidate the theory of Werner, that veins were filled with metallic solutions poured in from the upper part. Had this been the case, the nature of the rock could have made no difference in the quality or quantity of the ore.

Mr. Werner in his Treatise of Veins, states one instance, as if it were extraordinary, of the ore changing its quality, as the vein passed through different rocks, and is inclined to admit that elective affinity for the rock may have contributed to the effect. The circumstance, so far from being extraordinary, is of common occurrence, and known to all working miners. The entire cessation of the ore in one part of a rock, and its re-appearance below, are still more striking.

In Derbyshire the beds of metalliferous lime-stone are separated by beds of basaltic rock called toad-stone. When a vein of lead is worked through the first lime-stone down to the toad-stone, it ceases to contain any ore, and often entirely disappears: on sinking through the toad-stone to the second lime-stone, the ore is found again, but is cut off by a lower bed of toad-stone, under which it appears again in the third lime-stone. In strong veins particles of lead occur in the toad-stone, but in very small quantities.

If mineral veins were filled from above by metallic solutions, it is impossible to conceive that the nature of the rock should change the quality of the ore; much less could the ore disappear in one stratum, and appear again in a stratum below it. Nor could the vein be filled with melted matter ejected from below; for in either case it would be equally impossible to explain why the ore is separated by the toad-stone, though the vein is continued through it.—See plate II. fig. 5, where 1, 2, 3, represent the three beds of lime-stone, divided by the beds of stone *e* and *f*, and covered by sand-stone. When the vein *b* descends to the bed of toad-stone *e*, it entirely disappears; but on sinking through to the bed 2 the vein is found again; it disappears a second time at the bed of toad-stone *f*, and re-appears in the lower lime 3. Another vein *a a* is supposed to penetrate the beds of toad-stone *e f*, but contains no ore where it passes through them. The upper part of the vein *a* is represented as penetrating the superincumbent sand-stone, which is sometimes the case: in this part of the vein the most curious productions of the Odin mine near Castleton are discovered. In some situations where the beds of lime-stone are divided by seams of clay, provincially called way-boards, these way-boards cut off the vein as effectually as the toad-stone. Such facts prove that these veins were not filled from above. Professor Jameson has conjectured that the beds of toad-stone and lime-stone in Derbyshire, with the metallic veins, were all cotemporaneous, and that the toad-stone crossed through the veins at the time of their formation. But the different organic remains in the upper and lower beds of lime-stone preclude the possibility of their having been formed at the same time. The zoophytes in the lower bed of rock could not be living and coexistent with the shell-fish in the upper, nor with the vegetable remains occasionally found in the sand-stone which frequently covers the whole, and into which the veins sometimes shoot. Cuvier has well observed, that the existence of different organic remains offers incontestable proofs that the upper and lower strata in which they were found were formed in succession.

If metallic matter were not poured in from above, nor ejected from below, in what manner did it come into the vein?—The state of chemical science, and the facts at present known, are too limited to furnish a solution to this interesting question. There are, however, certain indications which may serve as a clue to future discovery. The variation of the mineral products in veins as they pass through different strata, seems to prove that the strata were efficient causes in producing this variation. Perhaps metallic matter was diffused through different rocks according to their elective affinity, and separated from them by Voltaic electricity, the different sides of the vein possessing different states of electricity; or the strata may act like a series of plates in the Voltaic pile, separating and secreting metallic matter from its different combinations. Some of the metals and other substances found in veins are capable of solution in hydrogen gas, and perhaps all of them may be so by natural processes; in this state they may have penetrated the vein and deposited their contents.

The discovery of the metallic nature of the very earths of which rocks are composed, and the probability that the metals themselves are compound substances of which hydrogen forms a part, open new views respecting the formation of metallic matter by natural processes, which may be within the reach of human power to develop, if not to imitate.

If metallic matter be now forming in mines, the process of its formation is extremely slow; but there are circumstances which appear to prove that it may in some instances be perceived. Mr. Trebra, director of the mines in Hanover, informed a gentleman of my acquaintance that he had seen a leather thong suspended from the roof of a mine, coated with silver ore: he has also observed native silver and vitreous silver ore coating the wooden supports left in a mine called Dreyweiber, in the district of Marienburgh, which had been under water two hundred years, and was opened in 1777.

Mr. Trebra was led from his own observations on mines to infer that metallic ores are formed by mineral exhalations, or were once in a gaseous state. Mr. Westgarth Forster, a practical miner in Northumberland, states, that at Wolfclough mine in the county of Durham, which was closed for more than twenty years, and opened again, needles of white lead ore were observed projecting from the walls more than two inches in length.

These and other phænomena observable in mines may convince us that there are processes going on at present in the great laboratory of the earth, and perhaps there are analogous processes taking place in the atmosphere, which may throw some light on these hidden operations of nature. The formation of saline matter on the surface of walls is a fact which merits more attention than it has hitherto received. Dr. Kidd, of Oxford, has recently published some very ingenious observations and experiments on the spontaneous production of nitre on lime-stone, which may lead to more important results than the learned Professor appears to have anticipated. These experiments show that neither the alkali nor the acid exists previously in the stone. Nor do they exist ready formed in the moisture of the atmosphere, dry frosty weather being particularly favourable to the rapid production of nitre, and moist weather the contrary.

When a portion of the wall was protected from access to the atmosphere by glass, which projected a little distance from the surface, the formation of nitre went on for a certain time and then ceased. The saline crystals were better defined and longer than on the parts of the wall. When the wall was coated with paint, crystals of nitre were even formed on the paint. The formation of carbonate of lead on the walls of the mine at Wolfclough may be analogous to the formation of nitre; and in both instances the surface of the wall and of the atmosphere may perhaps be considered as two galvanic plates in action, decomposing and recompounding the elements of metallic or saline matter from the atmosphere, or the gaseous fluids with which it is intermixt. The base of nitre (potassium) is known to be a metal; and could we seize nature in the act of producing a fixed alkali from more simple elements, we might compel her to reveal the process by which she prepares her metallic treasures in the deep recesses of the earth. Nor can the discovery be very remote; for we are already acquainted with the composition of the volatile alkalies, and are thereby enabled successfully to imitate nature in its formation.

When the matrix, or the substance which principally fills veins, is a soft unctuous clay, masses and particles of ore are often disseminated through it, varying in size from a pea to that of a large gourd, and are even sometimes of many tons weight. Masses of vein-stone are also imbedded in the same manner; and it is observed that the masses both of ore and vein-stone are of no determinate shape, and have generally the appearance of being corroded. Are we to conclude in such instances, that the hard minerals and metallic ores have been formed in the substance of the clay by some peculiar elective affinity, or that they once occupied the cavity of the vein, and have been all subsequently decomposed, except the remaining detached masses? I should be more inclined to adopt the former opinion; but it must be allowed that there are inexplicable instances of the disappearance of minerals which formerly existed in veins.

The formation of one mineral upon the crystals of another, and the disappearance of the crystal which has served as the mould, is indeed a common phænomenon in many English mines. I have before me a mass of rock crystal from Durham, formed on cubic fluor spar; but the crystals of the latter have entirely disappeared, leaving nothing but the impression of their form. In the mines of Derbyshire incrustations of calamine are formed on calcareous crystals, taking the shape of the dog-tooth spar; but in these false crystals no trace of the interior crystal is left. Certain local causes also appear to influence the crystallization of minerals in different districts, and dispose them to take peculiar secondary forms, which may be considered as appropriate to the minerals of that district. The pyramidal crystallization of carbonate of lime, called the dog-tooth spar (*Chaux carbonatée metastatique of Haüy*), is abundant in some of the mines of Derbyshire; whilst the same mineral rarely assumes that form in the mines of Northumberland and Durham, but is crystallized in other forms, which are equally rare in the Derbyshire mines. Fluor spar and barytes spar have appropriate forms in different districts, from which any deviations may be considered as varieties. The causes which occasion this diversity of secondary forms in minerals, whose constituent parts appear by chemical analysis to be precisely the same, are unknown. Nor are we able to explain in what manner the crystals before mentioned have disappeared: but these facts prove that the powers of nature extend beyond the present limits of science; and it is more consonant with the true spirit of philosophy frankly to acknowledge our ignorance, than to form systems from imperfect data, which can only serve to perpetuate error.

The following is a summary account of the rocks and situations in which the different metallic ores are generally found:—

Platina and the recently discovered metals called palladium, rhodium, osmium, and iridium, have only been discovered in the sands of rivers.

Gold and silver are found in primary and transition rocks, in porphyry and sienite, and in the lowest sand-stone. Gold has been occasionally discovered in coal, and very abundantly in the sands of rivers.

Mercury is found in slate, in lime-stone, and in coal strata.

Copper, in primary and transition rocks, in porphyry, sienite, and occasionally in sand-stone, in coal strata, and alluvial ground. Masses of native copper of many thousand pounds weight are found on the surface in the interior of North America.

Iron, in every kind of rock.

Tin, in granite, gneiss, mica-slate, and slate.

Lead and zinc, in primary and transition rocks, except trap and serpentine; in porphyry and sienite; in the lowest sand-stone, and occasionally in coal strata.

Antimony, in primary and transition mountains, except in trap and serpentine; it is also found in porphyry and sienite.

Nickel, bismuth, cobalt, in primary mountains, except lime-stone, trap, and serpentine. Cobalt and nickel also occur in transition mountains, and in sand-stone.

Arsenic, in primary and transition mountains, and in porphyry.

Manganese, in primary and transition mountains, and occasionally in the lower stratified rocks.

Molybdena and tungsten, uranium, and titanium, in granite, gneiss, mica-slate, and slate. The latter metals, with chromium, columbium, cerium, and tellurium, are very rare in nature, and can only be reduced to the metallic state with great difficulty.

Some instances are known of metallic veins being formed in the craters of volcanoes. According to Breislak, there is an ancient gold mine in the Island of Ischia, the whole of which island is entirely volcanic. The mine of mercury at Guanca Velica is in the crater of a volcano. The gold mine of Nagyag is also in a volcanic crater.

According to the disciples of Werner, flinty slate is not metalliferous; which is the more remarkable, as this is a very abundant rock, and is traversed by veins of quartz. It also alternates with and graduates insensibly into slate and gray wacke, the most metalliferous rocks. This offers a further proof, if any were wanting, to what I have stated in the ninth chapter, that the nature of rocks influences the quality and quantity of the ores they contain. How Mr. Werner and his disciples could close their eyes on this obvious fact, appears truly astonishing. It is a direct and demonstrative proof of the fallacy of the theory which they support*.

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* I have expressed my objections to the theory of Werner with less respect than many may think it entitled to;

but the confident, not to say arrogant, manner in which it has been supported, considering the preposterous claims which it makes on our credulity, is truly ridiculous, and will form an amusing page in the future history of science. The theory will be preserved from oblivion embalmed in its own absurdity. As an instance of the data which Mr. W. assumes as undoubted facts, take the following:—"In recapitulating the state of our present knowledge, *it is obvious that we know with certainty* that the floetz and primitive mountains were produced by a series of precipitations and depositions formed in succession; that these took place from water which covered the globe, existing always more or less generally, and containing the different substances which have been produced from them. We are also *certain* that the fossils which constitute the beds and strata of mountains were dissolved in the universal water."!!!—*Theory of Veins*, English translation.

CHAPTER XIII.

ON EARTHQUAKES AND VOLCANOES.

Phænomena preceding and attending Earthquakes —their Effects on Springs and Lakes—on Land —their connection with distant Volcanoes—more severely felt in Mountainous Countries than in Plains.—Indications of their Cause.—Volcanoes.—Phænomena preceding an Eruption.—Duration and Intervals of Volcanic Eruptions. —Submarine Volcanoes.—Eruptions of Mud and Water.—Number of active Volcanoes.—Source of Volcanic Fire deep below the Surface. —Opinions respecting it.—Hot Springs.—Magnitude of ancient Volcanoes.—On their Utility in the Œconomy of Nature.—Volcanic Products—solid, fluid, and volatile.

ACCUSTOMED to view the hills in our own country in a state of profound repose, presenting the same unvaried outline in each succeeding year, we can scarcely conceive the possibility of a whole district being covered with new mountains and another soil in the space of a single night. Yet such changes have been produced by the united agency of earthquakes and volcanoes within the limits of authentic history. I must refer the reader to the works of Dolomieu, Spallanzani, Sir William Hamilton, Humboldt, and other travellers who have attentively examined volcanic countries, for a description of these changes. The present chapter will be confined to the effects more particularly indicative of the connection between earthquakes and volcanoes, and the circumstances which may elucidate the cause of these awful phænomena.

Earthquakes and volcanoes may be considered as different effects produced by the agency of subterranean fire. They frequently accompany each other; and in all instances that have been observed, the first eruption of a volcano is preceded by an earthquake of greater or less extent. Volcanoes do not make their appearance in every country where the shock of an earthquake is felt: but earthquakes are more frequent in volcanic districts than in any other. Earthquakes are almost always preceded by an uncommon agitation of the waters of the ocean, and of lakes. Springs send forth torrents of mud, accompanied with a disagreeable stench. The air is generally calm, but the cattle discover much alarm, and seem to be instinctively aware of approaching calamity. A deep rumbling noise, like that of carriages over a rough pavement, —a rushing sound like wind,—or a tremendous explosion like the discharge of artillery, immediately precede the shock, which suddenly heaves the ground upwards, or tosses it from side to side, with violent and successive vibrations. The shock seldom lasts longer than a minute; but it is frequently succeeded by others of greater or less violence, which continue to agitate the surface of the earth for a considerable time. During these shocks, large chasms and openings are made in the ground, through which smoke and flames are seen to issue: these sometimes break out where no chasms can be perceived. More frequently stones, or torrents of water, are ejected from these openings. In violent earthquakes the chasms are so extensive that large cities have in a moment sunk down and for ever disappeared, leaving a lake of water in the place. Such was the fate of Euphemia in Calabria, in 1638, as described by Kircher, who was approaching the place when the agitation of the ocean obliged him to land at Lopizicum: " Here (says he) scenes of ruin every where appeared around me; but my attention was quickly turned from more remote to contiguous danger, by a deep rumbling sound, which every moment grew louder. The place where we stood shook most dreadfully; after some time, the violent paroxysm ceasing, I stood up, and turning my eyes to look for Euphemia, saw only a frightful black cloud. We waited till it had passed away, when nothing but a dismal and putrid lake was to be seen where the city once stood."

The extent to which earthquakes produce sensible effects on the waters of springs and lakes in distant parts of the world, is truly remarkable. During the earthquake of Lisbon in 1755, almost all the springs and lakes in Britain and every part of Europe were violently agitated, many of them throwing up mud and sand, and emitting a fœtid odour. The morning of the earthquake, the hot springs at Töplitz in Bohemia suddenly ceased to flow for a minute, and then burst forth with prodigious violence, throwing up turbid water, the temperature of which was higher than before: it is said to have continued so ever since. The hot wells at Bristol were coloured red, and rendered unfit for use, for some months afterwards. Even the distant waters of Lake Ontario*, in North America, were violently agitated at the time. These phænomena offer proofs of subterranean communications under a large portion of the globe; they also indicate, that a great quantity of gas or elastic vapour was suddenly generated and endeavouring to escape. From the fœtid odour perceived in some situations, it may be inferred that this gas is hydrogen or sulphuretted hydrogen. In other instances it may be steam, which condensing again would produce a vacuum, and occasion the external air to press downwards; which has been observed in mines immediately after the shock of an earthquake.

The space over which the vibration of the dry ground is felt is very great, but generally wider in one direction than another; and where a succession of earthquakes has taken place in the same district, it is observed that the noise and shock approach from the same quarter. It has been before mentioned that earthquakes are most frequent in volcanic districts; but the strokes are not the most violent in the immediate vicinity of volcanoes. On the contrary, they are stronger in the more distant part of a volcanic country. The ground is agitated with greater force, as the surface has a smaller number of apertures communicating with the interior. "At Naples and Messina, at the foot of Cotopaxi and Tungurahua, earthquakes are only dreaded when vapours and flames do not issue from the crater*." The connection which earthquakes have with distant volcanoes, and their frequency at particular periods, are truly remarkable. About the middle of the last century, after the earthquake at Lisbon, Europe, Africa, and America were for some time repeatedly agitated by subterranean explosions; which may be seen by referring to the journals of that time. Ætna, which had been in a state of profound repose for eighty years, broke out with great activity, and, according to Humboldt, some of the most tremendous earthquakes and volcanic eruptions ever recorded in history were witnessed in Mexico. In the night of the 19th of September 1759 a vast volcano broke out in a lofty cultivated plain, a tract of ground more than twelve miles in extent rose up like a bladder to the height of five hundred and twenty-four feet, and six new mountains were formed higher than the Malvern hills in Worcestershire. More recently (in 1812) the tremendous earthquakes in the Caraccas were followed by an eruption in the Island of St. Vincent's, from a volcano that had not been burning since the year 1718, and violent oscillations of the ground were felt both in the islands and on the coasts of America. It may be inferred from these circumstances, that the cause of earthquakes and volcanic eruptions is seated deep below the surface of the earth. During the earthquake at Lisbon, nearly all Europe and a great part of Africa felt the shock more or less severely: its effects were even sensible across the Atlantic. It is observed also that earthquakes are more severely felt in mountainous than in low countries. This might be expected from the structure of the earth*. In alpine districts, the primary mountains are not pressed with the incumbent mass of secondary rocks, and in such situations the resistance to a force acting from beneath will be much less, as all the weight of secondary rocks is removed. In very violent earthquakes, the secondary strata are broken or agitated; but proofs are not wanting, of lesser vibrations being stopped by their pressure. Humboldt says, he has seen workmen hasten from the mines of Marienburgh in Saxony, alarmed by agitations of the earth that were not felt at the surface. During the earthquake at Lisbon, the miners in Derbyshire felt the rocks move, and heard noises which were scarcely perceived by those above. That an expansive force acting from beneath is the proximate cause of earthquakes, can scarcely be denied; and the prodigious power of steam, when suddenly generated, seems equal to their production, if the quantity be sufficiently great. It is said that a single drop of water falling into a furnace of melted copper, will blow up the whole building. Now if we conceive a current of subterranean water to find access to a mass of lava many miles in extent, and most intensely heated, it would produce an earthquake more or less violent in proportion to the quantity of steam generated, and its distance from the surface. When the hydrogen gas lately exploded in a mine near Workington in Cumberland, a shock like that of an earthquake was felt by ships in the river at two miles distance.

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* It is the opinion of some travellers, that the lakes of North America were once the immense craters of antient volcanoes. It has been observed during many earthquakes in the Eastern States that the subterranean noise and motion appeared to commence from the Lakes, and proceed towards the Atlantic in a direction from the north-west.

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* Humboldt.

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* See a paper on earthquakes by the Rev. Mr. Mitchell, Philosophical Transactions, 1759.

The horrid crash like the rattling of carriages, which precedes earthquakes, is occasioned I conceive by the rending of the rocks, or parting of the strata through which the confined vapour is forcing a passage.

VOLCANOES are openings made in the earth's surface by internal fires; they regularly, or at intervals, throw out smoke, vapour, flame, large stones, sand, and melted stone called lava. Some volcanoes throw out torrents of mud and boiling water. Volcanoes most frequently exist in the vicinity of the sea or large lakes, and also break out from unfathomable depths below the surface, and form new islands and reefs of rock. When a volcano breaks out in a new situation, it is preceded by violent earthquakes, the heated surface of the ground frequently swells and heaves up, until a fissure or rent is formed, sometimes of vast extent. Through this opening, masses of rock with flame, smoke and lava are thrown out, and choke up part of the passage, and confine the eruption to one or more apertures, round which conical hills or mountains are formed. The concavity in the centre is called the crater. The indications of an approaching eruption from a dormant volcano are an increase of smoke from the summit, which sometimes rises to a vast height, branching in the form of a pine tree. Tremendous explosions, like the firing of artillery, commence after the increase of smoke, and are succeeded by red-coloured flames and showers of stones. At length the lava flows out from the top of the crater, or breaks through the sides of the mountain, and covers the neighbouring plains with melted matter, which becoming consolidated, forms a stony mass often not less than some hundred square miles in extent, and several yards in thickness. The eruption of lava has been known to continue several months. Intensely black clouds composed of a kind of dark-coloured sand or powder, improperly called ashes, are thrown out of the crater after the lava ceases to flow, and sometimes involve the surrounding country in total darkness at noon-day. Towards the conclusion the colour of the volcanic sand changes to white: it consists of pumice in a finely comminuted state. The quantity thrown out is sometimes immense. During an eruption of Ætna, a space of one hundred and fifty miles in circuit was covered with a stratum of this sand twelve feet thick. When the lava flows freely, the earthquakes and explosions become less violent; which proves that they were occasioned by the confinement of the erupted matter both gaseous and solid. The smoke and vapour of volcanoes are highly electrical.

The long period of repose which sometimes takes place between two eruptions of the same volcano is particularly remarkable. From the building of Rome to the 79th year of the Christian æra, no mention is made of Vesuvius, though it had evidently been in a prior state of activity, as Herculaneum and Pompeii, which were destroyed by the eruption of that year, are paved with lava. From the 12th to the 16th century it remained quiet for nearly four hundred years, and the crater was overgrown with lofty trees. It was descended by Bracchini, an Italian writer, prior to the great eruption of 1631: the bottom was at that time a vast plain surrounded by caverns and grottoes. Ætna has continued burning since the time of the poet Pindar, with occasional intervals of repose seldom exceeding thirty or forty years.

The eruptions of the Peak of Teneriffe have been very rare during the last two centuries. According to Humboldt, "the long intervals of repose appear to characterize volcanoes highly elevated. Stromboli, which is one of the lowest, is always burning. The eruptions of Vesuvius are rarer, but still more frequent than those of Ætna. The colossal summits of the Andes, Cotopaxi and Tungurahua scarcely have an eruption once in a century. The peak seemed to be extinguished for ninety-two years, when it made its last eruption by a lateral opening in 1798. In this interval Vesuvius had sixteen eruptions." The greatest eruptions of lava from Ætna and Vesuvius are always from the sides of these mountains; but these lateral eruptions finish by an ejection of ashes and flames from the crater at the summit of the mountain. In the peak of Teneriffe, this phænomenon has not taken place for ages; and in the recent great eruption of 1798 the crater remained inactive, nor did its bottom fall in.

Submarine volcanoes are preceded by a violent boiling and agitation of the water, and by the discharge of volumes of gas and vapour, which take fire and roll in sheets of flame over the surface of the waves. Masses of rock are darted through the water with great violence, and accumulate till they form new islands. Sometimes the crater of the volcano rises out of the sea during an eruption. In 1783, a submarine volcano broke out near Iceland, which formed a new island; it raged with great fury for several months. The island afterwards sunk, leaving only a reef of rocks. In December 1720 a violent earthquake was felt at Tercera, one of the Azores; the next morning a new island nine miles in circumference was seen, from the centre of which rose a column of smoke: it afterwards sunk to a level with the sea. A small island was formed in 1811 by a submarine volcano at a little distance from St. Michael's, one of the Azores: it was a mass of black rock, described by the Captain of the Sabrina frigate, who witnessed its formation to be equal in height to the high Tor at Matlock. A gentleman who visited the Azores in 1813 informs me that it had sunk down and disappeared: there is now eighty fathom water in the place.

Near Santorini, in the Grecian archipelago, submarine volcanoes have repeatedly burst forth during the last two thousand years, and formed several new islands: three of the ancient eruptions are recorded by Pliny, Strabo, and Seneca. The last eruption was in the year 1767.

If the sea or large lakes have once covered our continents, the greater part of the present and ancient volcanoes were once submarine. I am informed by Mr. Leckie that calcareous strata with organic remains rest on beds of volcanic tufa on the western side of Sicily, and decline towards the sea. This indicates that the volcanic fires in the vicinity of Ætna once raged under the ocean. Almost all the new volcanoes on record have broken out from under the sea.

Some volcanoes in Europe and many in the Andes throw out aqueous torrents intermixed with mud and stones; indeed, the American volcanoes more frequently eject mud than lava. Eruptions of water from Ætna and Vesuvius are rare, and some which have been described as flowing from the crater of the former, have been merely the torrents of melted water from snow on its summit. The volcano of Macaluba in Sicily presents the phænomena of mud, water, and stones thrown out of the crater. Ferrara describes an alarming eruption which took place on the 29th of September 1777: "Dreadful noises were heard all round; and from the midst of the plain, in which was formed a vast gulf, an immense column of mud arose to the height of about one hundred feet, which abandoned by the impulsive force, assumed the appearance of a large tree at the top. In the middle, stones of all kinds and sizes were darted violently and vertically within the body of the column. This terrible explosion lasted half an hour, when it became quiet, but after a few minutes resumed its course, and with these intermissions continued all the day. During the time of this phænomenon a pungent odour of sulphuretted hydrogen gass was perceived at a great distance, to the surprise of the inhabitants, who did not dare to approach this spot on account of the horrible noises. But many came the following day, and found that the new great orifice had ejected several streams of liquid chalk (*creta*); which had covered, with an ashy crust of many feet all the surrounding space, filling the cavities and chinks. The hard substances ejected were fragments of calcareous tufa, of crystallized gypsum, pebbles of quartz, and iron pyrites, which had lost their lustre, and were broken in pieces. All these substances form the outward circuit at this day. The unpleasant smell of sulphur still continued, and the water which remained in the holes was hot for many months, while a keen smell of burning issued from the numerous orifices around the great gulf, which is now completely filled."

In the Azores there are no less than forty-two active or dormant volcanoes; almost all the islands in the Atlantic, and many in the Pacific Ocean and the Indian Seas, are volcanic.

canic. A range of active and dormant volcanoes extends from the southern extremity of America to the arctic circle. Numerous volcanoes exist in Iceland; and the hot sulphurous exhalations from craters in various parts of Italy prove that their internal fires are not extinguished. Of the volcanoes in northern Asia, or the interior of Africa, we have little information, and the volcanoes covered by the sea cannot be estimated; but, from the above statement, we are authorized in believing that volcanic fires are more extensively operative than many geologists are disposed to admit. Their source is deeper under the surface of the earth, and many circumstances indicate that a connection exists between volcanoes at a vast distance from each other. In 1783, when the submarine volcano near Iceland suddenly ceased, a volcano broke out two hundred miles distant, in the interior of the island, and at the same time the great earthquakes took place in Calabria. On the night in which Lima and Callao were destroyed by an earthquake, four new volcanoes broke out in the Andes. Other instances of the apparent connection of earthquakes with distant volcanoes have been before stated.

Were the source of volcanic fires near the surface, the country in their vicinity would sink down*; and it is impossible to conceive how the same volcano could continue its eruptions incessantly for more than two thousand years, which is the case with Stromboli situated in the Lipari islands. Fragments of rocks, such as lime and gypsum, are thrown out of volcanoes unchanged by fire; which proves that the source of heat was deep below the range of these rocks: they have been merely driven up by the subterranean explosion, which forced a passage through them.

From the various phænomena which volcanoes present, we may with probability infer that the internal part of our planet is either wholly or partially in an igneous state, however difficult it may be to explain in what manner this heat is generated

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* Since the period of authentic history no great changes have taken place in the country round Ætna; but it appears from Virgil that an antient tradition existed of the sudden separation of Sicily from Italy.

> "Hæc loca, vi quondam et vastâ convulsa ruinâ
> Dissiluisse ferunt: cùm protinus utraque tellus
> Una foret, venit medio vi pontus, et undis
> Hesperium Siculo latus abscidit: arvaque et urbes
> Littore diductas angusto interluit æstu."—Æn. l. iii.

rated and confined. In every department of nature, our inquiries are terminated by ultimate facts, beyond which further research becomes vain. The constant generation and emission of light from the surface of the sun is more inexplicable and surprising than the constant generation of heat in the centre of the planets; but we cannot refuse our assent to the fact, though it is far beyond the power of the human mind to conceive by what means the particles of light are propelled through space with such astonishing velocity. We are too apt to measure natural operations by their coincidence with the received systems of philosophy, and to make our own ignorance the standard of truth. Had all the volcanoes in the world been dormant for the last two thousand years, and were we only acquainted with their existence by the writings of ancient historians, we should discredit the fact, and prove its impossibility by an appeal to established chemical principles; we should further accompany the proof with a pathetic lamentation over the credulity of former times.

The descent of stones from the atmosphere was denied during a longer period, though the fact is now established beyond all doubt: this should teach us to be less confident in our own knowledge, for there are still remaining "more things in heaven and earth than are dreamed of in our philosophy."

Admitting the existence of central fire in the earth, it is not difficult to conceive that there may be determinate causes, by which its intensity is increased or diminished at certain periods. We know little respecting the operation of electric or Voltaic energy in the laboratory of nature; but from the existence of electric light at the poles we may infer that electric currents are passing through the earth, and are important agents in many subterranean phænomena. Perhaps the different beds of rock which environ the globe may act like a series of plates in the Voltaic pile, and produce effects commensurate with their vast magnitude. Voltaic energy is capable of supporting the most intense degree of heat without access to atmospheric air, even in vacuo; and this for an indefinite time.

Whatever origin we ascribe to subterranean fire, there can be no doubt that it will make its way through the surface in those places where the incumbent rocks offer the least resistance, or where they are most fusible. By the access of water to this fire, the sudden evolution of steam, hydrogen gas, and many phænomena of volcanic eruptions, will admit of an easy explanation. Most of the active volcanoes being situated near the sea or great lakes, we may infer that water is in some way necessary to the production of volcanic phænomena. Boiling fountains and hot springs may be classed with volcanic phænomena; for it can scarcely be doubted that the Geysers in Iceland, which throw up columns of boiling water at intervals, to the height of seventy or eighty feet, are occasioned by the subterranean fires which extend under that island; to the same cause must be ascribed the boiling fountains in the island of St. Michael's, one of the Azores. The hot springs in the vicinity of the Pyrenees, and in Italy and other parts of the world, may with much probability be supposed to have a similar source of heat. The unvaried equality of their temperature for centuries, proves that this source lies far below the agency of those causes which operate on the surface. It has been remarked that hot springs are most frequent in volcanic and basaltic countries.

Though no active volcano exists in the Pyrenees, a late writer*, who has described the geology of these mountains, says that the hot springs and frequent earthquakes in different parts of this chain offer proofs of the present operation of subterranean fire.

The volcanoes in South America throw out water and mud, and stones of enormous magnitude; but for particular information respecting them I must refer the reader to the interesting descriptions of Humboldt, to Ulloa's Travels, and Molina's History of Chili.

The craters of ancient volcanoes which can now be traced, are many of them of far greater size than any that are in present activity. The whole of the mountainous parts of Quito, according to Humboldt, may be considered as one immense volcano, occupying more than seven hundred square leagues of surface, and throwing out flames by different cones, known by the denominations of Cotopaxi, Tungurahua, and Pichincha. In like manner, he adds, the whole groupe of the Canary Islands is placed as it were on one submarine volcano. The fire forces a passage sometimes through one and sometimes by another of these islands. Teneriffe alone contains in its centre an immense pyramid terminated by a crater, and throwing out from one century to another lava by its flanks. In the other Canary islands the different eruptions take place in various parts; and we no where find those isolated mountains to which volcanic effects are restrained. The basaltic crust formed by ancient volcanoes seems every where undermined, and the currents of lava seen at Lanzerote and Palma remind us, he adds, by every geological affinity, of the eruption which took place in 1301 at the Isle of Ischia, amid the tufas of Epimeo.

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* Déscription des Pyrenées, par M. Dralet.

The Hon. Mr. Bennet, in his account of Teneriffe, describes the appearance of the whole plain on which the present cone is situated as a vast volcanic crater. "After surmounting the lower sides of the mountain, at length an immense undulated plain spreads itself like a fan on all sides nearly as far as the eye can reach; and this plain is bounded on the W.S.W. and S.S.W. by the regions of the peak, and on the E. and N.E. by a range of steep perpendicular precipices and mountains, many leagues in circumference, called by the Spaniards Las Faldas. M. Escolar informed me that the wall could be traced for many leagues, the whole circumference of which evidently formed the side of an immense crater. This tract, called *Las Canales*, contains, according to the same authority, twelve square leagues. As we enter it from the S.W. there are to be seen several declivities of lava and strata broken inwards towards the plain, and evidently a continuation of the abovementioned line of wall, and the remains of the original crater." The cone of Vesuvius is thus partly encircled by the walls of a much larger crater, of which Mount Somma formed one of the sides.

The other extinct craters and souffrieres in the vicinity of Naples are of immense size compared with any that are in an active state. The magnitude of their opening must have been commensurate with the quantity of matter thrown out, for the craters themselves are formed by the eruptions.

We cannot avoid the inquiry respecting the use of these mighty agents in the œconomy of nature. Were we to consider volcanic craters merely as the vents for internal fires, a further inquiry would arise respecting the utility of these fires; for we cannot suppose that the laws which govern the interior of our planet are not directed by the same design and skill which are displayed in the external universe. Now the only instances which we have of actual rock formations in our own times are volcanic; and when we consider the vast number and the magnitude of extinct and active volcanoes, it will not appear unreasonable to suppose that they have been operative in forming the original materials of which all the various beds and strata that cover the globe were composed; and that these materials have been successively thrown out by aqueous and igneous eruptions in the different states of lava, sand, and mud, and also held in chemical solution or mechanical suspension by water. The further consideration of this inquiry will be resumed in a subsequent chapter.

The substances emitted or ejected from volcanoes are either solid, fluid, or volatile. Among the first, we may mention masses of rock ejected at the commencement of an eruption without being acted upon by fire. Among the melted substances may be enumerated lava, pumice, and volcanic glass. Lava is poured out of the crater or sides of a volcano, and descends in currents of red-hot liquid matter, of a pasty tenacious consistence like that of melted ore, or slag from a furnace. The quantity of lava ejected during a single eruption is sometimes inconceivably great. The current which flowed from Ætna in 1669 is two miles in breadth, fifteen miles in length, and two hundred feet in depth; it retains a portion of its heat to the present day. Ferrara says that in 1809, when this lava was perforated at Catania, flames broke out, and it continued to smoke at the surface, after rain, at the beginning of the present century, or 130 years after its eruption.

The following circumstance, communicated to me by a very intelligent glass-manufacturer, evinces the difficulty with which heat passes through vitreous substances. When the pot containing the melted glass cracks in the furnace, it is common to pour out the contents into water. A mass of melted glass in this situation will soon become cool and solid on the outside; but the internal parts will preserve a red heat for four or five hours after, and may be seen shining through the water when the temperature of the outside of the glass is but sensibly warm.

Lavas have generally a base* of hornblende or of felspar. Compact lavas with a base of hornblende have a near resemblance to basalts: they contain a considerable portion of iron, and attract the magnet: they melt into black scoriæ with the blowpipe: they have a dark or black colour, and are hard, sonorous, and heavy.

Lavas are frequently porphyritic, and contain crystals of felspar and mica, and crystals called by mineralogists garnet, leucite, olivine, augite, and vesuvian. Many of the lavas from Ætna are porphyritic, and receive a good polish. A small tablet in my possession contains thirty-six polished specimens of the lavas of different eruptions from that volcano, all varying in colour and external appearance.

Lava with a ground of felspar is generally gray. Compact lava commonly occupies the central parts of volcanic currents, and porous and vesicular lava the superficial part. The cavities in vesicular lava vary in size from that of a pea to a small nut: they are round or elliptical, and often contain a white radiated mineral called zeolite. Some lavas resemble the slags or scoriæ from furnaces; and the upper parts of currents of lava are often vitrified.

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* The mineral substance which forms the principal part of any compound stone is said to compose its base.

Currents and masses of undoubted lava often present the appearance of distinct stratification: in some instances this is owing to different currents of lava that have flowed and spread in succession over each other. In other instances the apparent stratification is owing to horizontal seams in the same mass, occasioned probably by contraction when cooling, and a tendency to crystalline arrangement. Volcanic powders or ashes are also frequently spread regularly over extensive tracts, and form beds alternating with currents of lava. Hence we may learn that stratification alone is not sufficient to disprove the igneous origin of rocks, which are in other respects similar to volcanic products.

The light-coloured or whitish porous lavas become fibrous, and pass into a light spongy stone called pumice. The island of Lipari contains a mountain entirely formed of white pumice: when seen at a distance, it excites the idea that it is covered with snow from the summit to the foot. Almost all the pumice-stone employed in commerce is brought from this immense mine. The mountain is not one compact mass, but is composed of balls or globes of pumice aggregated together, but without adhesion. From hence Spallanzani infers that the pumice was thrown out of a volcano in a state of fusion, and took a globose form in the air. Some of these balls of pumice do not exceed the size of a nut, others are a foot or more in diameter. Many of these pumices are so compact that no pores or filaments are visible to the eye; when viewed with a lens they appear like an accumulation of small flakes of ice. Though apparently compact, they swim on water. Other pumices contain pores and cavities, and are composed of shining white filaments. By a long continued heat pumice-stone melts into a vitreous semi-transparent mass, in which a number of small crystals of white felspar are seen. In all probability light-coloured gray pumice is formed from felspar by volcanic fires. Black or dark coloured pumice is more uncommon.

common. Humboldt says he has seen black pumice in which augite and hornblende may be recognised; he is inclined to think that such substances owe their origin to basaltic lavas which have assumed a capillary or fibrous form by intense heat.

Immense quantities of pumice are sometimes thrown up by submarine volcanoes. It has been seen floating upon the sea over a space of three hundred miles, at a great distance from any known volcano; and from hence it may be inferred that submarine volcanoes sometimes break out at such vast depths under the ocean, that none of their products reach the surface except such as are lighter than water.

Obsidian or volcanic glass so nearly resembles lumps of black glass, that they can scarcely be distinguished by the unpractised observer. Its broken surface is smooth, conchoidal, and shining: the most common colour of obsidian is a velvet black. The thinner pieces are translucent. It is harder than glass, and strikes fire with steel. It is common in the neighbourhood of volcanoes, and in some basalts which are most probably the products of volcanic fires now extinguished. In Lipari, one of the volcanic isles, the mountain de la Castagna, according to Spalanzani, is wholly composed of volcanic glass, which appears to have flowed in successive currents, like streams of water falling with a rapid descent and suddenly frozen. This glass is sometimes compact, and sometimes porous and spongy. Obsidian appears to be lava suddenly cooled: if a mass of lava or basalt be exposed to the heat of a glass furnace, it melts into a shining black or greenish black glass. Numerous veins of obsidian are said to intersect the cone of Mount Vesuvius, and serve as a cement to keep together the loose materials of which it is composed. Obsidian is sometimes ground and polished, and used for mirrors.

On the elevated plain which surrounds the conical peak Teneriffe there are masses of obsidian, which graduates into pitch-stone, containing crystals of white felspar. On the south-west side of the peak there is a stream of vitreous lava or obsidian several miles in length. Colonel Imrie describes a cement of lava in the island of Felicuda intermixed with obsidian, which had been flowing with it, and now formed part of the congealed stream. In some parts the obsidian is seen losing its brilliancy, and passing into granular lava; which becomes similar in colour, fracture, and texture to the other parts of the stream. Where the obsidian appears in a state of perfect glass, it is very near to where it has been first ejected from the side of the crater, and in a situation where it must have undergone a rapid cooling. In some parts of these congealed streams I could trace a transition of the obsidian into pumice. In these places the obsidian contained scattered air globules, which were almost always lengthened in the direction of the stream. These globules gradually augmented in number until the whole substance became a light, fragile, and frothy pumice*. Obsidian is found in the crater of Vulcano, one of the Æolian islands, and may be seen forming there at the present time†.

The mud ejected from the American volcanoes, becoming indurated, forms a solid mass of earth, and makes a new soil or surface frequently of vast extent and considerable depth. The volcanic sand and fine dust or powders thrown out of volcanoes during great eruptions, and spread over distant regions, sometimes forms a covering of many feet in thickness, which becomes consolidated by rain and moisture, and is converted into a substance called tufa. In its most indurated state tufa is used for building-stone: the softer kinds, which have a basis of clay, form tarras and puzzolano, substances of great use for making a cement which hardens under the sea; it is previously mixed with two thirds of common lime. Puzzolano is not only found in countries that are the seat of active volcanoes, but in places where volcanoes have long been extinct, as in Auvergne and other parts of France. According to Mr. Kirwan, artificial tarras or puzzolano is made by burning slate or clay that abounds in iron, and grinding them to a fine powder. Boiling water and bitumen are the principal liquid products of volcanoes. Petroleum or mineral oil sometimes trickles from the fissures of lava.

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* Memoirs of the Wernerian Society, vol. ii. p. 47.

† See Appendix.

In craters that are still burning, sulphur is very rare; almost all extinct volcanoes become mines of sulphur, called by the French *souffrieres*. When volcanic fires are in a state of activity at the surface, the sulphur combines with oxygen, and forms sulphureous acid gas and sulphuric acid; but in antient volcanoes the internal heat, though sufficient to sublime the sulphur, does not change its nature, for want of an access of air: the process is similar to the sublimation of sulphur in close vessels in the laboratory of the chemist. Almost all the sulphur of commerce in Europe is procured from the craters of dormant volcanoes in the south of Italy, Sicily, and the Lipari islands.

Muriat of ammonia (sal ammoniac) forms an incrustation on lavas soon after they cool. Muriat of soda, of copper, and of iron, and also sulphat of iron, or green copperas and alum, with specular iron ore and sulphuret of antimony, are among the products which are found in the craters of volcanoes.

The sulphureous and sulphuric acids formed by the combustion of sulphur during eruptions act upon lavas and rocks, and produce different combinations, of which the most important are alum, sulphat of magnesia, gypsum, and green copperas.

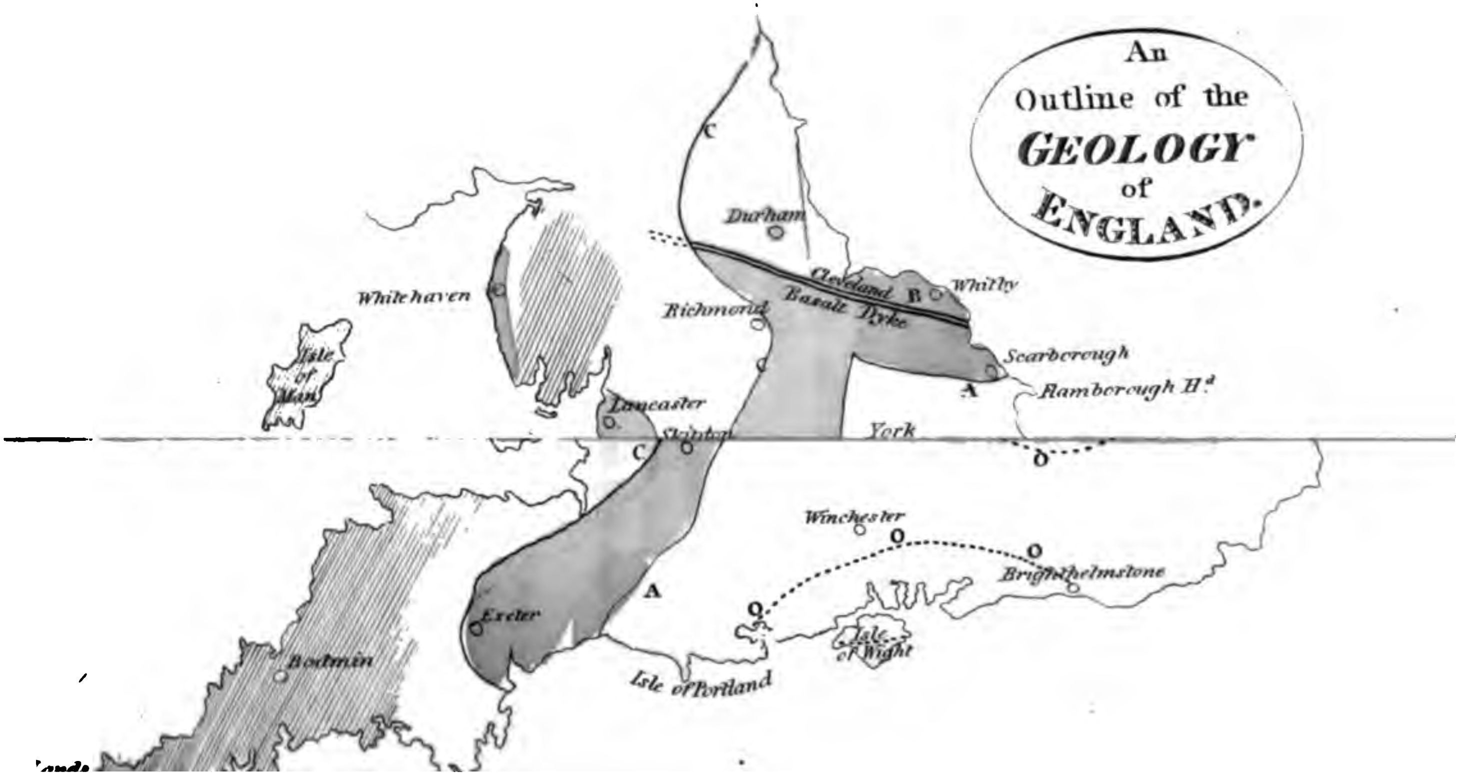
Hydrogen and sulphuretted hydrogen are emitted from volcanoes in vast quantities. Whether phosphorus be a product of volcanoes is unknown: its extreme inflammability prevents it from being discovered in a concrete form; but the dense white clouds like bales of cotton, which sometimes cover Vesuvius, resemble the fumes produced by the combustion of phosphorus. Among the products of volcanoes there are only three combustible at a moderate temperature: sulphur, hydrogen, and a small portion of carbon. It has been conjectured by Sir H. Davy, that the earths and alkalies which form lavas exist in the centre of the globe in a metallic state, and take fire by the access of water. This property of the newly discovered metals, to inflame instantly on the access of water, by which they are converted into earths or alkalies, offers an easy explanation of the origin of volcanic fires, could we suppose that substances so extremely inflammable and oxydable have remained for ages in a metallic state. There may, however, be processes going on in the vast laboratory of the globe that separate the earths from oxygen, and prepare them for the support of volcanic fires, by which they are thrown upon the surface, and thus establish a communication between the internal and external parts of our planet.

CHAPTER XIV.

AN OUTLINE OF THE GEOLOGY OF ENGLAND.

In the present chapter I propose to trace an outline of the geology of England, and the leading features of its physical structure and mineral geography. I wish the description, and the map which accompanies it, to be considered as presenting only a rapid sketch of the more important characters, without any attempt at minute accuracy of detail, which, were it attainable, would require an ample volume of illustration, and be more likely to fatigue attention than to excite or gratify general curiosity.

The shape of every island is determined by the different mountain ranges that traverse it. The inspection of an accurate map, in which the mountains and elevations are distinctly marked, will render this apparent. The length of Britain is determined by different groups of hills and mountains, which viewed on a grand scale may be considered as forming one chain extending along the western side of


An
Outline of the
GEOLOGY
of
ENGLAND.

of England and Wales, from Cornwall to Cumberland, and from thence to the northern extremity of Scotland. All the highest mountains in Great Britain are situated in this chain. The breadth of our island in the southern and eastern parts is determined by two lower ranges of hills: one of these extends from Dorsetshire to Kent; the other stretches in a waving line from the isle of Portland to the Wolds in the east riding of Yorkshire.

The western chain of mountains is broken, by the intervention of the Bristol channel and the low grounds of Lancashire and Cheshire, into three parts or ranges. For the sake of distinction they may be denominated the Northern, the Cambrian, and the Devonian range. Considered as parts of one chain, they constitute the alpine district of England, coloured red in the map, plate IV.

The line *A A A* nearly marks the direction of the range of calcareous hills or strata which extends from the west of Dorsetshire to near Scarborough. The line passes on the western side of Wiltshire, Oxfordshire, and through Northamptonshire, Leicestershire, Nottinghamshire, and the east riding of Yorkshire.

The country east of this line may be considered as forming the low district of England, coloured yellow in the map. The country on the west, between this line and the alpine district, may be denominated the middle district. These have marked geological characters, which we shall attempt to delineate, commencing from the coast of the low district.

In the geological examination of a district, see plate I. fig. 1, we may with equal advantage commence from the loftiest part, where the lowest rocks rise through the surface, as at *a*, and from thence we may descend over the rocks 2, 3, 4, 5, 6, describing them in succession; or we may commence from the sea shore, and observe the rocks 6, 5, 4, 3, 2, as they rise from under each other, to the surface, which they will do in some part of their course, if not dislocated by faults.

The low district is particularly distinguished by the absence of any regular beds of coal or metallic veins. It is principally composed of chalk and thick beds of sand and clay, with roe-stone, calcareous sand-stone, and earthy lime-stone, which were described in the ninth chapter. The highest hills do not rise more than six or seven hundred feet above the level of the sea except in a few instances. Chalk is the prevailing rock of this district: it has been described as consisting of two distinct formations distinguished by the lowermost being without flints. Chalk rises to the surface in the southern counties from Dorsetshire to Kent, and in the midland counties of Wiltshire, Berkshire, Hertfordshire, Buckinghamshire, Essex, Cambridgeshire, Norfolk, Lincolnshire, and the east riding of Yorkshire. In various parts of the low district the chalk is covered by thick beds of clay, particularly by a remarkably thick stratum which has been called the London clay because it extends over the vale of Thames in the vicinity of London.

The London clay is in some situations five hundred feet in thickness, and is distinguished by the variety of the organic remains which it contains, and by large nodules of imperfect iron-stone formed into septaria, or cells, by veins of calcareous spar. These are the balls from which Parker's Roman cement is made by burning. It is this clay which was cut through in forming the archway at Highgate. In the calcareous loam and marle over the London clay are found the bones of the elephant, the rhinoceros, the hippopotamus, the tapir, and the elk. They generally occur in low situations. At Brentford a vast collection of these bones were recently found in the grounds of Mr. Trimmer. About half a century since a large trunk of an elephant was discovered in sinking a well on the very spot where the present volume was printed near St. Andrew's Church, Holborn*. At Hampstead and Bagshot this clay is covered with sand and gravel. This very thick bed of clay appears to have been deposited in extensive lakes or basins formed in chalk. These lakes probably contained salt water, as the organic remains are analogous to the marine shells of tropical climates, but the existence of wood and vegetable products also in this stratum indicates that dry land existed in its vicinity. In its geological position and the fossils that it contains, it resembles what has been denominated the lower marine formation over chalk near Paris. The parts of the low district covered by this clay are marked in the map by the dotted lines *o o o*. Over this bed of clay there have been local deposits of strata which may be traced in some parts of the low district, but more distinctly in the Isle of Wight than elsewhere. On a more attentive examination of these strata, it has been discovered that they present the remarkable appearance of beds containing fresh water shells alternating with beds of marine shells; thus indicating a succession of changes and revolutions at the period of their formation, by which the surface has been alternately covered with salt and fresh water. For the knowledge of this curious fact we are indebted to Mr. Webster, from whose account of the Isle of Wight, in the second volume of Transactions of the Geological Society of London, it appears that the chalk and London clay pass under the channel called the Solent, and rise in the middle of that island, forming a range of hills, which extends from Culver cliffs on the east to the Needles on the west. It is truly deserving notice, that the strata of this range are here thrown into a vertical position, by one of those great convulsions of nature which so many circumstances indicate to have formerly agitated the globe.

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* For this information I am indebted to Mr. Parker of Fleet Street, whose father was present when it was taken out.

The whole thickness of these beds, which are nearly vertical, according to Mr. Webster's measurement, is not less than three thousand feet, including fourteen hundred and eighty-one feet of strata above the chalk, about nine hundred and eighty-seven feet of chalk, and five or six hundred feet of lower strata. Further south the strata under chalk are seen again in their original horizontal position, and on the northern side are hills composed of horizontal strata, evidently of a formation posterior to the time when the chalk strata were overturned. That the latter were once nearly horizontal, may be inferred from their always occurring in that position in the southern counties, and is rendered certain from the following circumstance described by Mr. Webster. In one of the vertical beds consisting of loose sand are several layers of flints, extending from the bottom to the top of the cliff. "These flints have been rounded by attrition, are from an inch to eight inches in diameter, and appear to have belonged to the chalk. Now it is inconceivable that these flints could have been originally deposited in their present position: they distinctly point out the former horizontal direction of this series. There are no signs of partial disturbance in these beds; the whole appears therefore to have been moved together." The enormous force required to occasion a displacement of the strata, not only through the whole island but into Dorsetshire, where it can be traced beyond Lulworth, must have been sufficient to form or destroy extensive lakes, and perhaps to separate England from the Continent.

Close adjoining the vertical strata on the northern side of the island occur a series of horizontal strata, which are distinctly visible in a hill called Headon:—these strata consist of an alternating series of fresh-water and marine deposits, bearing a striking similarity to the strata in the vicinity of Paris. According to Mr. Webster, they consist of

1 A calcareous stratum, containing only fresh-water shells.
2 Greenish marle with marine shells.
3 Marle with fresh-water shells.
4 Dark blue clay without shells.

Thus we have over chalk four distinct formations. A lower marine formation, which includes the London clay. A lower fresh-water formation, No. 1. The strata of this formation consist of sandy, calcareous, and argillaceous marle; some of them appear to be formed almost wholly of the fragments of fresh-water shells, without any mixture whatever of marine shells. "From the quantity of these shells, and the regularity and extent of the strata, we are compelled (says Mr. Webster) to admit that the spot where they now are was once occupied by fresh water, in which these animals existed in a living state. Over this fresh water occurs an upper stratum, which contains a vast number of fossil shells wholly marine; again, over this marine formation in the same hill, is a calcareous stratum fifty-five feet in thickness, every part of which contains fresh-water shells in great abundance without any admixture of marine exuviæ. Many of the shells are in high preservation, and the animals must formerly have lived in the very spots where they now are, the shells being so fragile that they could not have been removed from their original situation without breaking. Part of the stone of this formation is very hard and compact, and has long been extensively used for building stone. This stratum appears to have extended over the whole of the northern part of the Isle of Wight; but it has not yet been discovered in any other situation on this side of the water: it may be considered as the latest formation of rock we are acquainted with in England, and agrees in many of its mineralogical characters, and the fossils it contains, with the fresh-water limestone, *calcaire d'eau douce*, in the vicinity of Paris; they are different from any other known rock." But no where has there been discovered in the series of fresh-water strata in England any trace of the remarkable beds of gypsum containing bones of unknown genera, and species of quadrupeds, similar to the gypsum of Montmartre. See chapter 9.

Chalk appears above the surface in various situations in the southern counties from Dorsetshire to Kent, and in the midland counties of Wiltshire, Berkshire, Hertfordshire, Buckinghamshire, Essex, Cambridge, Norfolk, Lincolnshire, and the East Riding of Yorkshire. Chalk is also found below the surface in Huntingdonshire and Rutlandshire. The strata which lie under chalk, and may be considered as part of the same series, rise to the surface as we approach the coal districts, the general rise of these strata being to the north-west. The Rev. J. Townsend, in a work entitled "The Character of Moses vindicated as an Historian," has attempted to ascertain the succession and thickness of the strata from the chalk on the south coast to the coal districts in Somersetshire. The result of such a calculation must be liable to uncertainty from the difficulty of meeting with the strata uncovered, but it may deserve notice as an approximation to truth.

I shall state the order and thickness of the beds, preserving the same names which Mr. Townsend has given.

Soil and alluvial ground, various thickness:

Chalk, more than	400 Feet.
Three beds of green, gray, and red sand, with sand-stone	300
Clay in one situation	200
Superior oölite or roe-stone ..	40
Calcareous grit	30
Coral rag	30
Forest marble	40
Great oölite or Bath-stone ..	140
Clay	140
Inferior oölite and sand	80
Blue clay	70
Lyas	60
* Red marle	180

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* See Appendix.

Some beds of minor importance are not noticed in the above statement; and it is well known that these strata vary in thickness in different parts of their extent. The chalk in some situations is nearly one thousand feet in thickness, and the thickness of the strata which cover it, according to the statement of Mr. Webster, is more than fourteen hundred feet in the Isle of Wight. If, therefore, to the above estimate we add one thousand feet for the London clay and chalk, and for minor strata, which have been omitted, this would make the depth of the strata in the vale of Thames to the strata containing coal, about nine hundred or one thousand yards. If we suppose the lower strata accompanying coal to extend regularly under calcareous sand-stone and chalk-rocks, it would be a very interesting subject of inquiry to determine the accuracy of this estimate. The expense of such an experiment would be too great for any individual or private company; yet, when the coal fields in the north are exhausted, it will become an object of future public interest. Nor would the amount of the expense for various complete trials in different situations exceed that of the present national expenditure for one week.

The depth of the whole calcareous strata, from the upper chalk to coal strata, is not much more than twice the depth of some mines in England; and were we to commence operations where the chalk terminates in Bedfordshire, we should save the expense of sinking through one thousand feet or more of chalk and clay, which form the substrata near London. Where chalk terminates, and the subjacent sand rises from under it as at Woburn sands, the depth of the argillaceous strata containing coal is not greater than some of the present northern mines, if the strata have the same thickness in that county as in Dorsetshire and Somersetshire. Having arrived at regular argillaceous coal strata, how much deeper we must sink to gain the first bed of workable coal, could only be ascertained by trial: it probably would not exceed forty or fifty yards. I am, however, inclined to believe that the lower secondary strata do not extend to any considerable distance beyond their known limits, and that calcareous strata near the coast lie on primary or transition rocks, without the intervention of coal strata*. The determination of this question will be a subject of the highest national importance in the course of a very few centuries, when the coal fields which supply the metropolis and southern counties are worked out. Our prosperity and greatness as a manufacturing nation will depend on the result of this inquiry.

To the above remarks, given in the first edition of this work, I may now add, that a similar experiment has been made in that part of the low district which extends in the eastern side of the county of Durham, and is covered by calcareous strata, principally of the magnesian lime-stone. Many practical miners had asserted that the coal strata were either lost, or, as they term it, thrown out on the eastern side of this lime-stone, and did not dip or incline under it. J. Goodchild, Esq. who has extensive quarries in the lower strata of this lime-stone west of Sunderland, informed me that he had directed them to be bored through, and found underneath a very thick bed of argillaceous shale, under which were regular coal strata and beds of coal, which will be highly valuable when the old coal fields of that county are more exhausted; though, on account of their great depth, they would not repay the expense of working at the present time.

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* See Appendix

The northern extremity of the low district is broken by a range of lofty hills which intervenes, called the eastern moorlands, marked *B* in the map. It appears again beyond them on the eastern side of the counties of Durham and Northumberland.

The calcareous formation on the eastern side of England, which from its principal rock we may denominate the chalk formation, has three remarkable and extensive varieties of lime-stone. First, the chalk; secondly, roe-stone, similar to Portland-stone, and below this the magnesian lime-stone; bordering the coal strata various thick beds of clay and sand, above enumerated; occupy the intermediate space between these different lime-stones. The roe-stone is extensively spread, making its appearance in various parts of the low district from the isle of Portland in Dorsetshire to the east and north ridings of Yorkshire, but is not much known or noticed in the latter county. I have seen it *in situ* a few miles north-west of Doncaster;

it also appears north-east of Scarborough: it is here remarkably compact and indurated, and the ova or globules are too small to be distinctly seen without a lens.

The magnesian lime-stone, which immediately borders the middle district in many parts from Durham to Derbyshire, does not appear to extend into the southern counties. At least I am unacquainted with its occurrence, nor is it noticed in Mr. Townsend's account of the succession of the strata from the chalk to the coal. I am rather inclined to regard the blue clay and lyas*, as occupying the place of the magnesian lime-stone; and it may add further probability to this opinion, that the fossil remains of flat fish, which are common in the lias, have been found in the lower strata of magnesian lime-stone. To those who are desirous of studying the geology of the countries occupied by the chalk formation and the subjacent strata of the low district, I particularly recommend Mr. Farey's account of the series of strata subjoined in the Appendix, and the papers by Mr. Parkinson and Mr. Webster in the first and second volumes of the Transactions of the Geological Society.

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* Particular strata described in the Appendix by Mr. Farey.

The low district we have been describing, except various stones suited for architecture, contains few minerals particularly deserving attention. Iron pyrites is found crystallized in chalk rocks, and large crystals of sulphat of barytes have recently been discovered near Croydon in Surrey. Fullers earth is also peculiar to the strata under chalk. Iron-stone is found in part of this district, but is of little value where proper fuel cannot be obtained near it.

It has been previously remarked, that the number and variety of the organic remains found in the rocks and strata are the most interesting objects which this district contains.

The middle district, consisting of argillaceous and siliceous sand-stone and shale, is bounded on the east by the calcareous range of hills or strata forming part of the series described by Mr. Farey, (see the Appendix,) and extending from Dorsetshire to Yorkshire, near the line marked *A A A*. The western boundary from Northumberland to the county of Derby is formed by the metalliferous lime-stone mountains of the northern alpine district, or by mountains of coarse grit, called mill-stone grit, or by thick beds of shale, which rest upon lime-stone. This line is marked *C C C* in the map, and is continued into Somersetshire, to show that no metallic veins of any consequence are found east of it in any part of England *.

The secondary strata of the middle district extend west of the line *C C* till they touch the Irish sea on the coast of Lancashire, or are bounded by the alpine districts of Wales and Devonshire. On this side of England the strata are very irregular, and much broken by faults, and by occasional hills of transition and basaltic rocks which rise through them, and by branches from the mountains of Wales, particularly in the county of Shropshire, and in a line extending from thence to the hills of Charnwood forest.

None of the hills in the middle district rise higher than fourteen hundred and fifty feet above the level of the sea. The general elevation of the level country in the central parts of England may be determined by that of the canals. The Ashby de la Zouch canal, in its course to Oxford, unites with several others, along which a boat may pass seventy miles equidistant from the eastern and western sea (without the interruption of a single lock) at the level of two hundred and seventy-eight feet above the high-water mark at Gainsborough.

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* Ores of the copper and cobalt said to be recently discovered at Bramcote in Nottinghamshire are nothing more than the oxyd of iron.

The highest part of the middle district is the eastern moorlands of Yorkshire, or the Cleveland Hills, which rise more than fourteen hundred feet very abruptly on the north-eastern side. Aluminous schistus* of vast and unknown thickness forms the base of these hills, extending east and west about thirty miles from Robin Hood's Bay to Guisborough, Stokesly and Osmotherly. The breadth of the Cleveland Hills is about fifteen miles; but on their south side the alum slate is principally covered by sand-stone and marle, which belong, I conceive, to a peculiar coal formation. On the north-east the alum rock extends along the coast from Robin Hood's Bay by Whitby, Sands-End and Lythe to Huntcliff near Bretton, from whence it turns to the south-west to Whorlton. The coal formation covering a considerable part of these hills rises from under the oolite lime-stone. I have not had an opportunity of tracing the course of the strata on the south and south-west. According to Mr. Farey*, the basset or rise of these measures runs near Westow S.S.W. of Melton, by Spittel bridge, Sherriffe-Hutton, Coxwold, Thirsk, and from thence north-east to Danby Dale. The oolite limestone also makes its appearance very near the base of these hills near Pickering. In many parts the alum shale is covered by strata of sand-stone, iron-stone, shale, rubble or loose stone, and clay of the peculiar coal formation before mentioned. There is one seam of coal varying in thickness from four to eight inches or more. These strata are covered in some parts with alluvial soil in which the remains of the elephant have been discovered. Two grinders were found near Robin Hood's Bay in 1813. I measured the largest: it was nineteen inches round the base, and weighed thirteen pounds: it is in the possession of Mr. Sanders of Whitby, and exactly resembles the engraving given by Cuvier of the tooth of the fossil elephant with a flat crown.

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* The provincial name by which it is best known is alum shale.

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* Phil. Mag. vol. xixxx. p. 100.

The height of the alum cliffs, which rise perpendicularly from the sea, varies from one hundred to one hundred and forty yards. The characters of the stone are described in the eighth chapter.

Whitby Abbey stands near the bank of an awful precipice of alum shale which is undermined by every returning tide. When it was founded in 656 it is said to have been more than one mile from the sea; at present it is about two hundred yards from the edge of the cliff. This fact alone may prove the great encroachment which the sea is making on this part of our island. At low water the alum rock may be seen extending far to the east, forming a flat pavement, on which the observer may walk secure, treading at almost every step on the organic remains of the inhabitants of a former world, which are abundantly disseminated through the whole mass beneath, and projecting from the sides of the black and frowning cliffs above. Indeed a more desolate scene can scarcely be imagined, than that at Sands-End, north of Whitby, where the view of the cultivated country is hid, and nothing is visible but an immense floor of alum shale, surrounded on one side by dark overhanging precipices of the same rock, and bounded on the east by the cheerless German Ocean. The alum shale has been perforated near the sea, to the depth of one hundred and thirty yards, without discovering the subjacent rock; to which we may add the height of the cliffs above, which will make a total thickness exceeding two hundred and twenty yards. The upper parts of the bed are often more productive of alum than the lower. From the quantity of pyrites contained in this rock it sometimes takes fire spontaneously, when a heap of it which has fallen from the cliffs is moistened by sea-water. The animal remains are scattered through every part of the rock. They consist principally of numerous ammonites, nautili, belemnites, fossil vertebræ (supposed to belong to the shark), with bivalve shells.

Fossil-wood and jet are found in various parts of the rock. In walking over the natural pavement of alum rock on the coast, it is curious to observe that these animal remains are almost always surrounded by stone harder than the rest of the rock and projecting above it. In many parts they have formed around them spheroidal nodules, which may be detached like boulders from the rock. The ammonites are generally inclosed in these stones. In other instances a number of shells form a congeries included in one nodule. Some of the balls are compressed spheroids, very perfect in shape, consisting of iron-stone, and are burnt like those in the London clay to make Parker's cement. I consider the alum shale, and the strata which cover it, as a peculiar local formation subjacent to the roe-stone, but above the coal formation of Yorkshire or Durham. It has, I conceive, been formed in an extensive basin or lake, once extending far to the east, but the boundary on that side has been washed away. The organic remains are not those common to the coal strata, but to the calcareous strata and beds of clay above the coal. The alum slate is in fact a thick bed of indurated pyritoŭs slate clay, differing little, but in geological position and its organic remains, from some of the coal shales. At the time when this great bed was deposited, higher ground and dry land must I conceive have existed in the vicinity, as is evident from the quantity of fossil wood disseminated through it. The general position of the strata is nearly horizontal, and the whole are intersected by whin dykes, one of which has been described in the twelfth chapter, and is marked on the map plate 4.

The principal coal fields in the northern part of the middle district are in the counties of Northumberland and Durham, the west riding of Yorkshire, and Derbyshire. Coal strata terminate a few miles north-east of Derby, but appear again south of the Trent round Ashby de la Zouch. They are cut off to the south-east by the hills of Charnwood forest; and on the south-west they are covered by a thick bed of coarse breccia and gravel, which separates them from the coal fields at Polesworth and Bedworth in Warwickshire.

On the western side of the line *C C*, the red sand-rock described in the sixth chapter occupies a considerable part of the middle district from Cumberland to Shropshire. The principal salt springs and the rock-salt of Cheshire are in the vicinity or upon the red sand-rock at a low elevation, near a range of lofty hills, which extends from the high Peak of Derbyshire to Bromsgrove Lickey in Worcestershire, near the line marked *E E E* on the map.

There are many thick beds of sand-stone, coloured red, which are part of the regular coal formation, and overlie coal, near Oldham, Rochdale and Bury, and I believe in other parts of the western counties. Beside which, various detached coal fields surrounded by red sand-rock occur in Lancashire; but the greatest repositories of coal on this side of the line *C C* are in Staffordshire, and the part of South Wales bordering on the Bristol channel. The latter is one hundred miles in length, extending from Pembrokeshire into Caermarthen, Glamorgan, Brecon, and Monmouth: and its breadth in the broadest part is twenty miles; but in Pembrokeshire is not more than five miles. In the deepest part are sixteen beds of coal of various thickness, amounting together to ninety-five feet of coal, besides numerous strata from six to eighteen inches thick.

In the counties of Somerset and Devon the middle district we are describing is very narrow, the calcareous strata of the low district approaching near the granitic and schistose rocks. In the latitude of Manchester, and fifteen miles north of it, secondary strata extend from one side of the island to the other. The principal range of mountains which traverses the west riding of Yorkshire in that part, is no where sufficiently elevated to raise the subjacent metalliferous lime-stone.

As local illustrations are more interesting and intelligible than general descriptions, we will suppose ourselves crossing the island after landing at Hull. Here we should observe a flat country formed of alluvial ground. Peat, earth, and trees are frequently discovered below the surface, both on the Yorkshire side of the Humber, and also on the flat grounds on the coast of Lincolnshire*. A few miles west of Hull, the country becomes more elevated, and we pass over a range of chalk hills, which form the southern extremity of the York Wolds. Having crossed these chalk rocks near the Humber, we descend upon South Cave, and travel over allüvial ground covered with clay and gravel, which extends for more than twenty miles, by Howdon and Snaith, to near Nottingly and Ferrybridge, where the magnesian lime rock makes its appearance. The intervening space between the chalk hills and the magnesian lime is so completely hid by the alluvial soil, that the nature of the strata can no where be discovered; and it is only by analogy we can infer that they consist principally of calcareous sand-stone, roe-stone, and thick beds of sand and clay; but a little south of this line round Doncaster some beds occur analogous to those under chalk in the southern counties. The magnesian lime-stone forms hills of a low elevation distinctly stratified; the strata are nearly horizontal, and parted by seams of clay. The breadth of this range is here not more than three miles; it is succeeded by yellow siliceous sand-stone on which the town of Pontefract is built: we may consider this as the boundary of the low calcareous district. Proceeding in a direction towards Wakefield, we soon come upon the argillaceous coal strata of the middle district, which extend westward more than twenty miles. Wakefield and Leeds are seated near the eastern side of the coal district, and Huddersfield and Halifax near the western side. By referring to plate II. fig. 1. and observing the geological position of Sheffield over the coal strata, we may obtain a clear idea of that of Halifax and Huddersfield, which, like Sheffield, are situated near the western termination of the Yorkshire coal district. A few miles west of Sheffield, Huddersfield and Halifax, the same elevated range of hills composed of mill-stone-grit and shale rises from under the coal strata; see 3 and 5, plate II. fig. 1. In these two beds of rock, which together are more than three hundred yards thick, no workable coal is ever found; they rest upon metalliferous lime-stone, which makes its appearance west of the Derwent, near the latitude of Sheffield, but is no where visible in crossing the Yorkshire range in the latitude of Halifax and Huddersfield. Millstone grit forms the summit of Blackstone Edge, Pule Moss, East and West Nab, and all the higher hills in that part of Yorkshire.

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* This subterranean forest is coloured green in the map.

A perforation of three miles was lately

made through Pule Moss seven hundred and fifty feet below the summit of the hill, to form a tunnel for a canal from Huddersfield to Manchester. The tunnel appears to have been principally carried through the shale, which lies immediately upon lime, hence called lime-stone shale. I form this opinion from an examination of the hill, and the stone thrown out from the excavation. The strata are elevated and inclined in an opposite direction on the east and west sides of the hill, and are intersected by a large dyke, containing a vein described by Mr. Outram the engineer* to be lime-stone. At a considerable distance from the entrance a number of balls were found composed of argillaceous iron-stone: they are oblate spheroids from three to twelve inches in diameter, having lines drawn upon their surface parallel with the largest diameter, from which many of them have a projecting point or stalk; which proves that they were not formed by attrition. The two lowest beds of good workable coal in the west riding of

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* Philosophical Transactions, for 1796. See Appendix.

Yorkshire rise to the surface, and terminate a little east of the town of Halifax. Thick beds of sand-stone, corresponding in position with the mill-stone grit and shale-grit of Derbyshire, rise to the west, and extend to Blackstone Edge and near Todmodon, where the same beds are bent in an opposite direction, and then generally follow the curvature of the hills. Near Ovendon, a little west of the town of Halifax, coal was bored for to the depth of two hundred and twenty yards, but without success. Proceeding towards Manchester, we descend the steep western declivities of these mountains to the plains of Lancashire; and leaving the mill-stone grit and shale grit, we again come upon coal strata, which further west are cut off, or partially intercepted, by the red siliceous sand-stone before described, provincially called the red rock. The coal measures or strata of Lancashire do not agree with those of Yorkshire. The principal beds of coal are, one of six feet in thickness, and a lower one called The three quarter bed. They extend from the vicinity of Oldham to near Rochdale and Bury in Lancashire, but their continuity is broken by numerous faults and deep valleys. Near Oldham the sand-stone strata accompanying coal have a dark red colour, and have been mistaken by some persons for the red rock, which appears further west, and cuts off the regular coal strata: but detached coal fields occur in hollows lying on or surrounded by this rock*. The surface of Lancashire is covered in many parts by beds of gravel; and in clay pits under the surface are found detached blocks of granite, basalt, sienite and slate, similar to the rocks in North Wales and Westmoreland. From near Prescot to Liverpool the red rock forms the immediate substratum, and may be seen dipping under the waves of the Irish Sea. Had we crossed the island in a line twenty-five miles south of this, near the latitude of Sheffield and Chester, we should travel over a similar series of rocks,—with this difference, that beyond the vale of Derwent twelve miles west of Sheffield, we should meet with the metalliferous lime-stone of Derbyshire, which rises to the surface at Castleton. See plate II. fig. 1, 7. After leaving the lime-stone mountains of Derbyshire, and crossing the red sand-stone of Chester, should we continue our line into Wales, we should again meet with the same metalliferous lime-stone in Flintshire, forming the boundary of the alpine district, and resting upon slate. Had we crossed the island in the latitude of Lancaster, we should observe the metalliferous lime-stone mountains of Craven in Yorkshire rising from under the grit-stone and shale, and resting upon coarse slate, and in some instances upon red sand-stone which appears to alternate with slate. In this latitude the grit-stone mountains of Wharfdale and Netherdale approach near the earthy lime-stone on the eastern side, and nearly exclude the regular coal district. They are said to contain the oxyd of manganese. Sulphat of strontian and sulphat of barytes also occur in the rocks bordering the rivers Nid and Wharf. In some situations in this part of Yorkshire thin seams of coal are found in hollows or basins in the grit-stone *. These are of limited extent, and the seam is seldom more than twenty inches thick. At Hudswell moor the lowest and thickest part of the coal is one yard, but the stratum diminishes and vanishes at the edges. The extent of this coal is about one mile in each direction.

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* If this red sand rock, which has been frequently represented as the old red sand-stone of Werner, subjacent to mountain lime-stone, be really that rock, the mountain lime-stone must have been cut off in this direction by a great fault, or its continuity has been broken by some other cause. From the constant occurrence of this rock in England at a low level, I am inclined to doubt its identity with the old red sand-stone of Werner.

In passing across the island from the coast of Kent to Cornwall, we should travel over chalk and calcareous sand-stone for more than one hundred and fifty miles to the west of Dorsetshire, and from thence should pass over a few miles only of the lower secondary strata, before we arrived at the transition and primary rocks of Devonshire and Cornwall. Another section across the narrowest part of the island will be subsequently described.

The most valuable mineral products of the middle district are coal, iron-stone, and rock-salt, described in the sixth chapter.

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* Near Middleham and at Scrafton, Leyburn, Thorp Fell near Burnsell, and as far west as Kettlewell, on a hill called Centre Lights, there are several small detached coal basins provincially called Swilleys. The position of the coal seams in these basins is represented plate II. fig. 2.

For the information respecting these small repositories of coal, I am indebted to Colonel Smithson of Heath Hall near Wakefield.

It has been before stated, that an assemblage of lofty mountains passing along the western side of the island constitutes the alpine district of England and Wales. These mountains are broken into three ranges by the intervention of the Bristol channel and the plains of Lancashire and Cheshire.

The northern range enters Cumberland from Scotland, and passing through that county and Westmoreland, extends its branches into Northumberland and Durham. It is continued along the western side of Yorkshire, with the north-west part of Derbyshire, and from thence into Staffordshire*.

The mountains and valleys of the northern range form the fascinating scenery round the lakes of Cumberland and Westmoreland, the gloomy grandeur of Craven in Yorkshire, and the romantic dales of Derbyshire. A magnificent view of the loftiest part of the northern range presents itself on the road from Kirkby Lonsdale to Kendal: or on crossing the sands from Lancaster to Ulverstone, a more extended and distant view, comprising the principal mountains of Cumberland and Westmoreland, is seen from the heights of Stanmore, on the road from Appleby to Richmond in Yorkshire. Helvellyn, Saddleback, Skiddaw, and the mountains near Winandermere and Coniston, are distinctly conspicuous. Whoever has charmed away a portion of his existence among these mountains, whose forms he can here recognise at the distance of forty miles, will

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* Some traces of the rocks which compose the metalliferous mountains in Derbyshire may be discovered on the south side of the county, particularly at Ticknal, where the metalliferous lime-stone makes its appearane, and where a vein of lead ore is worked, belonging to Lord Ferrers.

> "cast a longing, lingering look behind,"

as he turns from them for the last time in passing southward.

The highest mountains of Cumberland, Westmoreland, and Craven in Yorkshire rise about three thousand feet above the level of the sea. Snow remains on their summits and northern declivities to the middle of June; and in some instances has continued the whole year. Snow was gathered on Helvellyn in August 1812. The following admeasurements of some of these mountains taken by the barometer were given me by Mr. John Dalton of Manchester, well known by his chemical discoveries, and his New System of Chemical Philosophy. I shall add the trigonometrical measurement by Colonel Mudge. The difficulty of bringing both these modes of admeasurement to coincide is well known.

	Dalton. feet.	Mudge. feet.
Scafell, Cumberland	3240	3166
Helvellyn ditto	3225	3055
Skiddaw ditto	3175	3022
Grasmire ditto	2865	2756
Saddleback ditto	—	2787
Coniston-Oldman ditto	2571	2577
Cross Fell ditto	2901	—
Bowfell, Yorkshire	3084	2911
Whernside, Craven, ditto	2475	2384
Ingleborough ditto	—	2361
Pennygent ditto	—	2270
Pendle Hill, Lancashire		1803
Holme Moss, between Cheshire and Yorkshire		1859
Axe Edge, Derbyshire		1751
Lord's Seat ditto	—	1715

Scafell, the highest mountain in England, is lower than Snowdon in North-Wales. A specimen from the summit given me by Mr. Dalton, is a flinty slate of a greenish gray colour, the external part is marked with the lichen geographicus. Kinder Scout, the highest mountain in Derbyshire, is not given in the Survey by Colonel Mudge; but I am informed by Mr. Brown, engineer, of Derely in Cheshire, that in taking a level for a projected canal with a very accurate instrument by Ramsden, he found the elevation of a ridge below the summit of this mountain to be seventeen hundred and thirty-six feet above the high-water mark on the Cheshire coast. From this point the summit of the mountain (by the estimation of Mr. Brown) rose about four hundred feet. According to this statement, the elevation of the highest part of Derbyshire is two thousand one hundred feet above the sea.

The eastern side of the northern range of mountains from Cumberland to Derbyshire is composed of subcrystalline metalliferous limestone, covered in many parts by the coarse mill-stone grit and shale grit previously described. In the south-west part of Yorkshire, this lime-stone is entirely hid by the incumbent grit for more than twenty miles; but in the north-west it rises to the surface, and forms most of the mountains of Craven: it is seen resting on slate in Swaledale, and at the base of Ingleborough, and in other parts adjoining Westmoreland. The slate in Swaledale

dale is gray and purple; a coarse gray wacke slate is also found there. Some of the limestone from this part of Yorkshire is polished for chimney pieces: it is similar to that of Derbyshire.

The highest mountains of Cumberland and Westmoreland have without sufficient reason been said exclusively to belong to the class called transition rocks. Any marked distinction between transition and primary rocks does not perhaps exist in nature; but if we class granite, gneiss and mica slate as primary, and for the convenience of description call those districts in which they predominate primary countries, and those which abound most in slate, flinty slate, gray wacke, porphyry and sienite, transition countries, we may call the district including the higher parts of Cumberland, Westmoreland, and the north-west of Lancashire, a transition country. But highly crystalline granite exists in parts of this district, particularly near Shap in Westmoreland. Some of the mountains in the neighbourhood of Ullswater are capped with basalt.

A section across this part of our island is particularly interesting in a geological view. I shall

I shall therefore accompany it with a sketch representing the general arrangement of the rock formations from the Sunderland lime-stone on the German Ocean to the coal formation of Cumberland on the Irish Channel, plate VII. fig. 1. The magnesian lime-stone of the low district *A* is seen rising above the level of the sea marked L L. Proceeding west, we come upon the coal strata *B B* before we reach Durham, which continue across the county to near Wolsingham, rising in succession to the west or south-west, but much intersected and broken by faults. Here, various beds of crystalline sand-stone, coarse sand-stone or grit, and indurated shale, continue to rise in the same direction, containing a few seams of coal. Metalliferous lime-stone soon makes its appearance further west, *C C*, but no where forms those immense cliffs (more than eighty or a hundred yards in thickness) which we meet with in Craven in Yorkshire and in Derbyshire. The lime-stone here is divided into eighteen beds by interposing strata of sand-stone and shale. The total thickness of the different lime-stones is about one hundred and fifty yards; of which the second is about twenty-one yards, and is called the great lime-stone. Nearly the lowest bed of lime-stone is forty-two yards in thickness, and is called the Melmerly Scar lime-stone from forming cliffs at that place, from whence it extends into Westmoreland. The whôle of the strata are intersected by veins which are very productive of lead and zinc, in the lime-stone particularly in what is called the great lime-stone, but produce much less ore as they pass through the sandstone strata, and rarely produce any in the beds of argillaceous shale. The highest point of the metalliferous lime-stone district is Cross Fell. It is composed of various beds of alternating lime-stone, and covered near the summit by the lower series of the coal strata: it is intersected by a great vein of lead ore running east and west and rising to the surface: on one side is a mass of basalt, with an extraordinary circular cavity, surrounded by basaltic columns. Cross Fell is the only mountain in England from whence both the eastern and western shores of our island are said to be seen: snow remains longer upon it than on any other in the northern counties: it has even been known to continue the whole year. This may be attributed to its distance from the vicinity of either sea*. The strata continue to rise in the same direction westward till we pass Cross Fell, but are broken by faults, particularly by a fault called the Burtreeford Dyke, which runs north and south through the west side of Durham crossing the Wear at Burtreeford. It has thrown down the strata to the west one hundred and sixty yards. The strata as they approach it rise at an angle of about twenty-five degrees, see X. Descending the western declivities of Cross Fell and the other mountains of this district, we come to the red sand-rock extending from thence beyond Penrith, marked *D*. The thickness of all the different beds from the magnesian lime-stone to the red sand-stone, as given by Mr. Westgarth Forster*, is about thirteen hundred yards. On the western side of the red sand-rock, and at the feet of the high mountains near the lakes, we meet with hills and beds formed of loose fragments of pebbles washed down from these mountains. Such conglomerated beds are generally found on the borders of alpine districts. Different coloured lime-stones which receive a high polish, occur near Kendal and other parts surrounding these mountains. The rocks of the more alpine part E E of this district are composed of roof-slate, flinty-slate, horn-stone, porphyry, gray wacke, green-stone, sienite, and granite: they present no regular features of stratification or order of succession. The beds of the schistose mountains are very elevated, but, like Skiddaw, are frequently covered with vegetation. The porphyritic and granitic rocks are more craggy, bare, and precipitous. The depth of the lakes by no means corresponds with the height of the mountains, being not more than a hundred and forty yards. The rocks near the vale of Newlands and Buttermere have a red and at a distance a burnt appearance, particularly Red Pike, a small-grained granitic rock composed principally of felspar spotted with chlorite, approaching almost to a sand-stone. Beyond these mountains to the west we meet with a thick bed of siliceous sand-stone, and then the Cumberland coal formation extending to the sea marked F. The lime-stone district furnishes a large quantity of lead some of which is rich in silver.

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* The remarkable phænomenon provincially called the helm wind, frequent on Cross Fell, is well deserving more attention than it has received. It is described by persons who have passed over the mountain at the time, as an impetuous wind rushing violently in every direction from under a cloud which hovers on the summit. The effect is felt many miles distant from the mountain; and in the tracts of country over which these currents are most frequent, the progress of vegetation is much retarded.

On entering the cloud the air is said to be perfectly calm, though immediately below it the force of the wind was so strong as to make it difficult to stand. The noise which proceeds from the part whence the wind rushes, resembles the roaring of a cataract.

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* In a very valuable little tract called "A Treatise on a Section of the Strata, &c." of which I have given an account in the Phil. Mag. March 1815.

The mountains in the vicinity of the lakes contain some copper and lead. The best plumbago in Europe is got from a mountain in Borrowdale. In that part of Lancashire which adjoins Westmoreland between Ulverstone and Furness Abbey a large quantity of red hematite is procured: it is imbedded in an unctuous clay, which leaves a metallic stain on the fingers. This ore yields the most ductile iron produced in the united kingdom: it is particularly valuable for the manufacture of card wire.

The remarkable agitation of the waters which occasionally takes place in the lakes of Keswick and Bassenthwaite, particularly of the former, is well deserving the attention of philosophers. I have never had an opportunity of observing it in either: but those persons who reside on the banks describe it as a motion commencing from beneath, violently heaving up the waves, and rocking with considerable force the boats that may be crossing the lake. At other times the surface appears as if disturbed by heavy drops of rain. The air remains calm and dry. Both these appearances are precisely what are described as taking place in water before the violent shocks of an earthquake, or the eruption of volcanoes, and we are led to refer these motions to a cause connected with the same phænomena. Indeed, a view of the nearly circular lake of Keswick, with the steep surrounding cliffs, when seen from the summit of Skiddaw, recalls to mind the circular lakes formed in extinct craters, so well depicted and described by Sir Wm. Hamilton in his

Campi Phlegræi*. The breadth of England in the line of section here given is little more than one hundred miles. Though the geological position of the mountain lime-stone appears the same with respect to the coal strata and the magnesian lime-stone as that of Craven and Derbyshire, yet the great difference in the division and alternation of the beds would seem to indicate that, though they may all be considered as similar but independent formations, they were probably formed in detached lakes, or basins, under circumstances which occasioned a considerable diversity in the order of succession.

The rocks of Derbyshire, which form the southern part of the northern range of alpine country, have been already described as consisting of lime-stone and basaltic amygdaloid. The lowest bed of this lime-stone has not been sunk through, nor is it sufficiently elevated in any part of the county to discover the subjacent rock; but from the similarity of this rock with the lime-stone mountains of North Wales, York-shire, and Lancashire, we may infer that like them it rests upon slate*. The whole thickness of the three beds of lime-stone and basaltic amygdaloid or toad-stone is more than two hundred and fifty yards; but in some situations the basaltic amygdaloid is of vast and uncertain depth, varying much in this respect in different parts where it has been sunk through. The fourth or lowest lime-stone is much thicker than any of the upper beds, which is evident from excavations made in it by rivers and mines. I have before given Mr. Townsend's estimate of the thickness of the strata from chalk to coal in the southern counties; and if we could suppose the same to extend regularly to the northern counties, we might form an estimate of the whole thickness of the secondary strata of England, as an admeasurement has lately been taken of the coal strata and subjacent rocks in Derbyshire, of which I have received the following account from a friend:—"Our present manager at the Alfreton coal works has a horizontal section in preparation, which will show the succession of all the strata from the magnesian lime-stone on the east to the fourth lime-stone of Derbyshire, determined from actual observation. I have a perpendicular section of his now before me, comprising the same range of rocks. From this it appears that the total depth taken on the level line of the measure, of all the known Derbyshire strata, including the small portion of Nottinghamshire, which contains the yellow or magnesian lime, is thirteen hundred and ten yards. In the whole of this range, I find there are thirty different beds of coal varying in thickness from six inches to eleven feet, and that the total thickness of coal is twenty-six yards. Of course the above estimate can only be considered as an approximation to truth, since the thickness of the strata was taken upon a level line, and not perpendicular to the line of their inclination. If we knew the angle of the dip in all cases, accuracy might be obtained, and of this we shall in all probability be put in possession by the horizontal section before mentioned."

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* A phænomenon in some respects analogous, was described to me by Mr. Leckie, whose account of the state of Sicily merits the profound attention of the political philosopher. At the foot of a range of hills, the great Hyblean chain, there is a small lake of rain water nearly circular. The water is cold, but it constantly boils up in the middle, and smells strongly of bitumen, and large lumps of it are often gathered on its banks. The lake is thirty-two miles S. S. W. from Ætna.

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* The slate and lime-stone appear sometimes to alternate with red sand-stone in Yorkshire. I have never seen the junction of this sand-stone with the lime-stone of Craven; but I am informed by the Hon. Mr. Bennet that it may be seen at Chasterton near Kirkby Lonsdale.

I have already described the thickness of the strata of the low district (from Mr. Townsend's estimate) to be about seven hundred yards, which is the depth that must be sunk through from the upper strata of the chalk districts to reach the coal strata; or, according to the thickness of similar strata in the Isle of Wight (p. 349), the depth would be one thousand yards. The series of the coal strata and metalliferous lime-stone in Derbyshire here given is thirteen hundred yards, through which we must pass to the lowest lime-stone, that is probably incumbent on slate. This lime-stone is not yet sunk through; but if we estimate its thickness, including strata that may intervene before we reach the slate, to be four hundred yards, this added to the above, will make the depth of the slate rocks below the stratum of clay in the vale of Thames one mile and a quarter, supposing the secondary rocks to extend regularly below the surface from the centre of the island to the eastern coast, which I have before said I believe is not the case, for the beds of basaltic amygdaloid do not extend beyond the Peak of Derbyshire; and the mountain lime-stone of that district appears to terminate near the south side of that county as it approaches the hills of Charnwood Forest in Leicestershire.

These hills form an important feature in the geology of England, being composed of rocks considered by many geologists as primary surrounded by secondary strata. They extend about ten miles in a line from S.E. to N.W., rising from six hundred to near eight hundred feet above the circumjacent country. The forest is now under cultivation, and in the course of a few years the surface will be concealed by plantations and inclosures, which have already covered the distant declivities of these hills, and hid from our research the extent of the rocks in different situations westward, where they evidently rise near the surface. I suspect they are connected with the basaltic rocks near Nuneaton in Warwickshire, and extend still further under the surface till they unite with the rocks in Shropshire and Wales.

The strata surrounding the forest are nearly horizontal, consisting of sand-stone with minute fragments of slate and chlorite. This sand-stone, with strata of marle, is seen covering the rocks at the Swithland slate quarries, and near the village of Whitwick. Similar beds of sand-stone extend on the north-east side of these hills into Nottinghamshire. Thick beds of breccia and gravel, composed of fragments of these rocks, are found in the country in the north-west side of these hills. The strata of the Ashby de la Zouch coal field approach on this side within about half a mile of the porphyritic rocks at Whitwick, rising at a very elevated angle. Between the last elevated bed of coal and the Forest rock, the intervening space is filled by horizontal strata of sand-stone evidently of posterior formation to the coal strata. A mile to the north-west of this place, a thick bed of stratified lime-stone rests on the flanks of these hills, which may be seen rising from under

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it by ascending a rivulet called Grace Dieu Brook. This lime-stone I consider as the extremity of the Derbyshire shale lime-stone*, which may be traced from near Ashburn to Wold Park, eight miles north of Derby; and on the south to Breedon, Cloudshill, and finally to its termination at this place. Some beds of this lime-stone are singularly contorted; a representation of that at Wold Park is given. Plate III. fig. *e*, *e*, *e*, shows the bending of the lime-stone. *FF* is a bent stratum of chert resembling flint.

The lime-stone on the other side of the forest at Barrow on Soar is of that kind which has been called the lias limestone; it contains fossil remains of flat fish, with the form perfect, and the scales preserving their pearly lustre. These fish are found in flattened balls of lime-stone, imbedded in the marle which divides the strata.

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* This lime-stone is occasionally imbedded in the thick shale which covers the lower beds of metalliferous lime-stone. Nodules of lead ore were discovered in the soil on excavating the canal from Swannington to near Loughborough on the north-east side of the Charnwood Forest hills. I conceive these were the remains of metallic veins existing in lime-stone that once covered the declivities of the hills.

The hills of Charnwood Forest may be said to represent in miniature the mountains of North Wales, and those in the vicinity of the Lakes. They are principally composed of flinty slate, roof-slate, horn-stone, porphyry, porphyritic green-stone, and sienite. No organic remains have been observed in any of the Forest rocks, nor in the slate-quarries which have been extensively worked for many years. Veins of white quartz containing chlorite intersect these hills, particularly in that part between Bardon Hill and the town of Whitwick. No appearance of any metallic substance occurs in these veins *, nor is pyrites found in any of the rocks which I examined: a rock containing a great quantity of yellow mica, at a place called Basil Wood, has been erroneously stated to contain pyrites. The roof-slate is principally confined to the eastern side; and on this side the beds are more regular, and rise at a very elevated angle to the south-west, and would by many geologists be described as most distinctly stratified. Such

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* Except a few spangles of micaceous iron ore.

they appeared to me on the first examination; but I am persuaded that what resembles stratification is the result of a process analogous to crystallization on the mountain mass, by which it has separated into thick tables or plates, that are of limited extent, and terminate in the shape of a wedge. The slaty cleavage of the stone is nearly at right angles with the direction of the beds. All the rocks of this district, except the porphyritic rocks on the west side, have a tendency to assume pyramidal forms, and the stone divides into trapezoids with smooth faces, by which they may be distinguished at a distance from any other stones in that part of England.

The changes by which the different kinds of rock pass into each other are similar to those described by D'Aubuisson in the department of La Doire*. In the same rock the upper bed will sometimes be porphyritic and the next compact; and sometimes from the same bed small specimens might be broken, which will present the two characters on the opposite sides. The large-grained sienite of one rock becomes smaller-grained in another, and in the adjoining rock it will be porphyritic, and pass by gradation into flinty slate with small crystals of felspar.

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* Le passage d'une de ces variétés de roche à l'autre, provenant de la différence dans les proportions des principes, est aussi brusque qu'il est fréquent. Dans le distance de quelques pas on voit tantôt un schiste presque entièrement formé de feldspath, tantôt très abondant en quartz, tantôt formé de talc presque pur.—*Journal des Mines*, Mai 1811.

I am inclined to believe that these rocks are cotemporaneous, and were formed from one homogeneous mass; but circumstances attending their formation have disposed the parts to assume various arrangements in different situations. Perhaps the whole may be considered as nearly allied to basaltic rocks. Veins of dark green-stone intersect the sienite at Mount Soar Hill. The sides of the vein are intermixt, and closely united with the rock.

I have not seen the basaltic rock or green-stone near Nuneaton *in situ*; but the stones brought from thence for the roads have the same trapezoidal forms as those on Charnwood Forest, and have also a strong internal resemblance to some of them, and belong, I conceive, to the same formation. In some of the sienite on the eastern side of the forest the hornblende disappears, and it becomes what might be called true granite.

The granitic rocks of Mount Sorrel are separated from the slate rocks by a plain, called Rokeby plain, which prevents their junction from being traced on this side; they have a lower elevation than the slate, which is inclined as if it rose from under them. Bardon Hill is composed of sienitic porphyry, Beacon Hill is composed of flinty slate; but some of this slate contains crystals of felspar, and is porphyritic. These are the two highest hills in the forest. The gradations from sienite to porphyry and flinty slate are frequent on the western side of the forest. The only mineral substances obtained from these hills is slate, paving-stones, and a species of whet-stone or hone; this is not found in a regular bed, but in fragments under the soil. The beautiful green and red sienite at Markfield Knowl might be employed for durable ornamental architecture; large pyramidal blocks are scattered over the hill, and were a quarry opened near the summit, the stone might probably be raised in large masses at a small expense.

The porphyritic rocks near Whitwick, particularly one called Sharpless, are composed of a dark purplish gray compact horn-stone; it contains numerous crystals of quartz, and some of felspar. The rocks on this side of the forest are singularly shattered*, and present deep perpendicular fissures, in some instances covered by transverse stones of immense size. No trace of external crystallization appears; but we observe piles of shapeless ruins, showing the devastation of the elements and the effects of all-destroying time.

I have been more minute in the description of this part of England than may appear consistent with the mere outline of its geology which I proposed to give; but so little was known respecting the mineralogy of these hills, though in the centre of the island, that I trust I shall be excused for this deviation. The country presents few scenes to allure the picturesque traveller, and the surface will soon be nearly concealed by plantations and inclosures. The observations were made during a mineralogical examination of some of the manors on the forest for the Earl of Moira.

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* Those "whose minds proud science never taught to stray" have their modes of explaining the cause of every remarkable appearance in nature, which sometimes display as much inventive fancy as the speculations of the philosopher. My guide on this part of the forest, a respectable farmer, observing my attention fixt on these rocks, gravely said, "Sir, this is a strange place; all these rocks were rent asunder at the time of the crucifixion, which we read of you know in the Testament." An opinion so harmless, and which offered such a visible confirmation of his faith, it would have been cruel to disturb.

On the western side of England, as we approach the alpine districts, we occasionally meet with rocks of a similar class to those in Wales, but surrounded by the secondary strata of the middle district: of these, the Malvern hills on the borders of Herefordshire and the Wrekin and Caradoc hills in Shropshire are the most considerable.

The Malvern hills are from eleven hundred to fourteen hundred feet high, and extend for ten miles, rising on the eastern side from the flat country on the vale of Severn; on the western side they are connected with a range of lower hills, which extend several miles into Herefordshire.

The central parts of these hills are principally composed of granitic rock, consisting of the common ingredients of granite, but mixed with hornblende in various proportions, and presenting a great variety of appearance. The lower declivities are covered with lime-stone and sand-stone. For a particular account of the mineralogy of the Malvern hills, I refer the reader to a valuable paper by Mr. L. Horner in the first volume of the Transactions of the Geological Society.

The surface of Shropshire is much broken by basaltic rocks, and other rocks which connect the hills on the western side of the county with the alpine district of Wales, or what I denominate the Cambrian range.

The Wrekin and Caradoc hills, with the hills in their vicinity, belong to those of basaltic formation, being composed of a variety of green-stone and amygdaloid: some of these rocks contain the mineral called actinolite. On the sides of these hills are singular beds of clay-stone, containing cells or cavities, varying in size, but seldom exceeding that of an almond; they are flattened and elongated, as if by pressure since their formation. The Clee hills, the highest in the county, belong to the coal formation, but are capped with basalt, as described in page 146.

The loftiest mountains of the Cambrian range extend through Caernarvonshire and Merionethshire. They decline in height as they pass through Cardiganshire and South Wales, and dip under the coal strata on the borders of the Bristol channel. Branches from this range spread through the western counties of Wales, and part of Herefordshire and Shropshire.

I have only seen the mountains called the Rivals at a distance; but their conical or pyramidal form so nearly resembles that of the greater and lesser Sugar Loaf on the opposite coast of Wicklow, that I think it extremely probable they are both composed of the same kind of quartz rock, which is well known to assume this form in various parts of the world. By some persons they have been mistaken for volcanic craters; but the conical form is occasioned by the higher parts of the rock being broken into detached blocks, which roll down and accumulate round the base, where they remain uncovered by vegetation, and scarcely subject to further decay.

Snowdon in Caernarvonshire, and some of the other mountains in that county, are from three thousand four hundred to three thousand five hundred and seventy feet above the level of the sea, which is above one hundred yards higher than any of the mountains in Cumberland. A magnificent view of that part of the Cambrian range which extends through Caernarvonshire, is seen from the southern point of the Isle of Anglesea, on the entrance of the Menai; here the whole of the Snowdonian mountains may be comprised in one view from Penmanmaur on the northern coast, to the conical mountains called the Rivals on the furthest southern extremity of the county, Snowdon rising immediately in the midst of this range.

Rocks of lime-stone containing lead and zinc, similar to the lime-stone of the northern range, compose many of the mountains on the eastern side of North Wales; some detached coal fields occur on the lower declivities of these hills, and in basins or troughs in the counties of Flint and Denbigh. This lime-stone rests upon different varieties of slate rock, which are seen rising from under it as we proceed west. In this direction we meet with a succession of mountains principally composed of gray wacke, flinty slate, and roof-slate, intersected by veins of quartz containing copper pyrites, and occasionally with green-stone, porphyry, and sienite.

Organic remains are sometimes discovered in the slate of North Wales as well as in that of the higher Alps, which may serve to prove the impropriety of the term primary, as applied to slate. No considerable rocks of granite are known to rise above the surface in Wales; but the occurrence of loose pieces of granite indicates that it exists in parts of that district, and also in Anglesea. The rocks in Anglesea have generally a low elevation, and rise through the soil in small ridges or detached peaks. Large blocks of extremely hard green-stone lie near the shore opposite Bangor ferry. In a narrow cavity or basin running from near the centre of the island northwards to the sea, there is a detached coal field, which I am informed by Mr. Farey rests upon lime-stone. The beautiful serpentine of this island has been described: see page 94.

The western side of the island of Anglesea abounds in rocks allied to serpentine, particularly talcous slate, which appears to pass into fine mica slate, intersected by small laminæ of quartz, which are in some parts straight and parallel, in others they are singularly waved and contorted. I consider the mica-slate near Bray and Killiney on the opposite coast of Ireland, as a continuation of the same rock; and as the basin of the Irish channel is no where deep in this direction*, it might, I conceive, not be impossible, though it would certainly be unprofitable, to form a tunnel under the Irish channel. There is one at present formed at a greater depth under the surface in the county of Durham, which extends one-fifth part of the distance, supposing the work to commence on each side.

On the eastern side of Radnorshire, near Old Radnor, are two mountains called Hunter and Stanner, which are principally composed of a greenish mineral substance, nearly allied to serpentine, called by mineralogists diallage or smaragdite; it is intermixt with steatite. Further west, at Llandegley, there is a range of jagged rocks composed of cellular clay-stone, which resembles lava: the cells are compressed, and lined with hematite. Sulphurous springs and beds of sulphurous lime-stone, with the shattered appearance of the rocks in this part of the county, all impress the mind with the belief of the former agency of subterranean fire. Similar indications may be traced from Shropshire in this direction to Cader Idris in Merionethshire. Cader Idris, one of the loftiest mountains in that county, has near its summit a vast conical cavity resembling a volcanic crater: the north side of the mountain is covered with scattered basaltic columns composed of porphyritic green-stone already described in the fifth chapter. An interesting sketch of a group of these columns, taken by Henry Strutt, Esq. of Derby, with a camera lucida, is given Plate V, and may be relied upon as a correct representation, without that heightening of the effect which we are insensibly disposed to give to striking objects when copied by the eye. The accuracy of the outline will be more valued by the mineralogist than the tints and shades of a finished drawing. The figure was intro-

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* I have not a chart of the soundings to refer to, but I believe they are not more than seventy fathom in any part.

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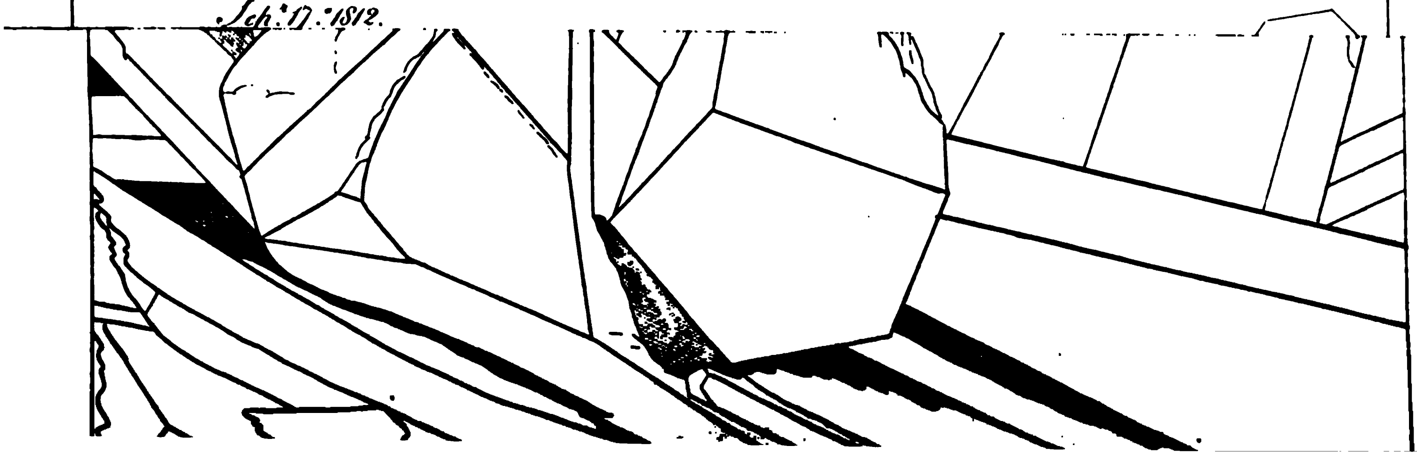
Pl. 5.

Basaltic Columns on the
N. Side of Cader Idris
Sep.r 17.th 1812.



duced in the sketch as a standard of comparison. The crystals or columns represented in this plate, were observed in an excavation on the north side of the mountain, after an unusually violent thunder storm which had taken place a few weeks before. The surface of the ground appeared recently torn up, and the colour and angular sharpness of the columns further proved that they had been exposed but a short time to the atmosphere, which soon changes the colour of this stone, and renders it considerably lighter. The original position of these columns has evidently been disturbed by some violent concussion. This circumstance was referred to in a preceding chapter. The reader will excuse the repetition, as this mountain presents objects particularly interesting to the geologist, there being no other situation in South Britain where the columnar structure of the rock is so strikingly displayed on a large scale.

The mountains on the north side of Radnorshire are principally gray wacke passing from greenish schistose sand-stone to coarse slate. I was shown a number of detached rock crystals found in the soil in one part of the county, which resemble in every respect the stones from Cairngorum in Scotland; but I had no opportunity of examining the situation, to discover if any rock existed in the vicinity which contained similar crystals.

The rocks which bound the coal field of South Wales on its western extremity in Pembrokeshire are composed principally of hornblende and felspar, intermixed in various proportions. With these are associated schistose rocks and others resembling a fine grained conglomerate. These rocks in their structure and constituent parts bear a striking resemblance to the porphyritic sienites and other rocks on Charnwood forest in Leicestershire.

Lime-stone abounds in the southern parts of Wales; it is the foundation rock of the great coal field extending from Pembrokeshire to Monmouthshire, and may be seen rising from under the coal, and forming the boundary of the coal strata which lie arranged in an extended concavity formed in this lime-stone. The principal mineral treasures of the alpine districts in Wales are copper, lead, and slate; and of the less elevated districts, coal and iron-stone: but much remains to be done, and many years will probably elapse before we are accurately acquainted with the mineralogy of this part of the island. Perhaps there are few districts in Europe that contain more hidden treasures that would amply reward the proprietors for the expense or labour of scientific research.

The Devonian range spreads through part of Somersetshire, passing through Devonshire and Cornwall, and terminates at the Lizard Point and the Land's End. Similar rocks make their appearance in the Scilly Islands, in the islands of Jersey, Guernsey, and Alderney, and on the opposite coasts of France. The highest part of this range is formed by the mountains of Dartmoor in Devonshire, which is stated at fifteen hundred feet above the level of the sea; but few of the mountains in Cornwall have more than half that elevation. The strata of the middle district rise at an elevated angle as they approach the granite rocks of this range. Metalliferous lime-stone and slate or killas form the western boundary of the coal district

strict in Somersetshire, and range along that county into Devonshire and Cornwall.

A chain of granite mountains extends from Dartmoor in Devonshire to the extremity of Cornwall. Their declivities, and sometimes their summits, are covered with rocks of slate and killas, and occasionally by variously coloured lime-stone. The killas of Cornwall appears to occupy the place of mica slate; the finer kind has a silky lustre, and seems nearly allied to that rock. At the Lizard Point the rocks of granite are covered by a schistose micaceous rock and by serpentine; but the latter is far inferior in beauty to the serpentine in Anglesea*. Rocks composed of diallage occur near the serpentine in Cornwall. Soft steatite called soap rock, very much valued in the manufacture of china, is found imbedded in serpentine. Decomposed white felspar or kaolin, produced from the granite rocks of Cornwall, is also employed in the manufacture of china and the finer kinds of pottery.

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* Those parts of the alpine districts where granitic or schistose rocks occasionally rise to the surface are shaded by lines in the Geological Map.

Slate and marble are supplied from many parts of the Devonian range; but the treasures for which this part of England is most distinguished are the ores of tin and copper. For the former our island was visited by the first commercial nations of antiquity. The mines of tin are far from being exhausted; but the ore must have been more abundant formerly than at present. This is evident from the pebbles of tin ore found a little under the surface in the plains and valleys of Cornwall. Tin ore, or tin stone as it is called by mineralogists, is extremely hard, and there can be little doubt but these water-worn fragments once formed a part of regular veins which intersected mountains that have been decomposed and worn down. From the manner in which this ore is procured by removing and washing the surface of the ground, it is called stream tin. The deepest mines in Cornwall are that called Cook's Kitchen, which is four hundred and twenty yards, and the Dolcoath mine, which is at present worked at the depth of four hundred and fifty-six yards from the surface. Tin stone is sometimes disseminated through granite.

A black crystallized mineral called schorl, a species of tourmaline, is also intermixt with some of the granitic rocks of Cornwall, and sometimes constitutes the principal part of the rock. Beside copper, tin, and lead, this range contains ores of silver, cobalt, bismuth, manganese, antimony, zinc, and iron. Pieces of native gold are occasionally discovered in the sands of rivulets in a similar situation to stream tin; some of these pieces are as large as a field bean. All the known metals are found in Cornwall in greater or smaller quantities, except platina, mercury, molybdena, tellurium, tantalium, columbium, and cerium.

The annual value and produce of the copper and tin from the mines in this district were as under:

		Copper ore.	Copper.	Per ton.	
				£.	£.
1808	Cornwall	73,434 —	7118	107 —	781,348
	Devon	3,725 —	369		
1809	Cornwall	72,038 —	6972	122 —	875,784
	Devon	3,210 —	365		
1810	Cornwall	76,525 —	6651	141 —	969,376
	Devon	3,713 —	854		
1811	Cornwall	70,000 —	5948	125 —	767,379
	Devon	3,540 —	323		

Average

Average annual value of tin	Tons.	£.
From 1790 to 1800, per ann.	3245	227,047*.

In a general view of the geology of England, the hot wells and warm springs must not be neglected. The warm springs in Derbyshire vary in temperature from 58 to 82 degrees, though each spring preserves the same degree of heat except in situations where the waters have been intermixt with those near the surface by excavations made in mines or by other causes. The effects of internal heat appear to extend under the whole district that contains basaltic amygdaloid or toad-stone, for the rivers of this county are rarely frozen except in still situations when the thermometer is little more than 10 degrees above zero. A very sensible degree of warmth may be perceived in the water of the Crumford canal between Matlock and Crich, and numerous exhalations from warm springs may be frequently seen rising from the neighbouring hills. The warm springs of Bath and Bristol have a much higher temperature than those of Derbyshire, owing probably to their being less intermixt with the waters near the surface, as they issue from fewer apertures. It has been remarked that warm springs are principally confined to basaltic and volcanic countries. In Iceland, in the Azores, in Sicily, in Italy, and various parts of Europe not distant from volcanic or basaltic rocks, numerous warm springs exist; but in the whole of the United States of America, where there are few basaltic rocks, warm springs are scarcely known*.

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* This account of the produce of the Cornish ores is extracted from the article *Mines* in Dr. Rees's Cyclopædia, to which I refer the reader for an excellent statistical account, by John Taylor, Esq. The advantages of local and practical information which this gentleman possessed, combined with requisite science, render the whole of this article particularly deserving attention.

These remarks are confirmed by the situation of the warm springs in Derbyshire, surrounded by beds of basaltic rock nearly allied to lava. The hot springs of Somersetshire are situated on the western side of the island, not far from the line of basaltic rocks extending from the coasts of Wales and Ireland to the Hebrides, and terminating at its northern extremity, in the volcanic mountains of Iceland. It will scarcely be denied that the boiling fountains or geysers of that country, and the warm springs of Italy, Sicily, and St. Michael in the Azores, derive their temperature from subterranean fire; and it is contrary to the established rules of philosophy to multiply causes and seek for other sources of heat in the waters of Bath or Buxton.

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* Essai sur la Geologie des Etats Unis, par W. Maclure, —*Journal de Physique*. Warm springs are said frequently to rise on the side of basaltic dykes.

The former have preserved their high temperature for two thousand years: hence it is obvious that they rise from a great depth, far below the effects of those changes which take place near the surface. It is further remarkable that the hot wells of Bath and the boiling fountains of Iceland both contain in solution siliceous earth, one of the most insoluble substances in nature: the similarity of their contents affords a further confirmation that they derive their heat from the same cause, and we have every proof the subject will admit of that this cause is subterranean fire*.

We have no record or tradition of volcanic eruptions in our island; hot springs are the only phænomena that clearly indicate the existing activity of subterranean fires: but if the igneous origin of basaltic rocks be established, we have abundant evidence of their prior operation on an extended scale from the centre of England to the Irish channel, and from thence to the furthest extremity of Scotland. Nor is it impossible, or highly improbable, that volcanic fires may again break out on the western side of our island:

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* Temperature of the Hot Waters in England, and some other parts of Europe.

	Fahrenheit.
Bristol	74°
Matlock	66
Buxton	82
Bath	112 and 116
Vichy, Auvergne,	120
Carlsbad, Bohemia,	165
Aix la Chapelle, Flanders,	143
Borset, near Aix la Chapelle,	132
Bareges, South of France,	120

the internal agitation of the waters of Keswick lake in Cumberland, called the 'bottom wind,' and the subterranean noises and earthquakes frequent near Comrie in Perthshire, may with much probability be classed with volcanic phænomena. A volcano that was dormant for more than two thousand years suddenly broke out in Calabria in 1702; and Vesuvius is known to have had periods of repose for several centuries. The inhabitants of Pompeii and Herculaneum had as much confidence in the stability of nature as the present inhabitants of Bath, when they were overwhelmed in a moment by a volcanic eruption which buried themselves and their cities, and left no trace on the surface of their former existence. In contemplating these great revolutions which have changed the surface of the globe, we are not to consider the powers of nature extinct, because their periods of activity may extend beyond the reach of human observation.

The future is concealed from our view; nor would it be wise to encourage the disposition described by the poet, which anticipates remote calamity, and

"——trembles at impossible events,
Lest aged Atlas should resign his load,
And heaven's eternal battlements rush down."

We are, however, too much engrossed by the present, and occupied with the cares or amusements of life, to be in great danger of having our peace disturbed by speculations respecting the future condition of our planet. When earthquakes and volcanoes, those awful ministers of nature and providence, desolate a country, resignation is the true philosophy of the sage. The evils which nature inflicts are transient, and bear no proportion to those with which man torments his fellows. It may fairly be doubted whether all the destructive effects of subterranean fires, of lightning, inundations, and earthquakes, since the earliest records of history, have produced half the sum of human misery felt in those countries which are the present seats of war *. These evils are indeed only known to us at a distance: hence we regard them with indifference, if not with complacency, and contemplate a state of warfare as the natural and proper condition of civilized society.

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* In 1813.

It is hoped that the sketch here given of the geology of England will be received with candour, if not with indulgence, as an attempt to present in a concise form the leading features of its mineral geography. To fill up the outline and complete the picture of each district with accuracy, would require the labour of many active and intelligent observers, continued with diligence for a long period of time; and if we are to reason from the little progress these inquiries have already made, we may predict it will never be accomplished. It is now more than two thousand years since our island was visited by the Phœnicians for its mineral treasures; yet at the present day almost all that is known of the mineralogy of England, is what ignorance and chance have discovered. Though tin ore was procured from Cornwall in the earliest ages of the world, the ores of copper in the same district were totally neglected till the beginning of the last century, and much later most of our utensils of copper and brass were imported from the continent. In Derbyshire, where mines have been worked since the time of the Roman conquest, one of the richest ores of lead was unknown and thrown away so late as the year 1804; and the ores of zinc were employed for mending the roads in that county, in the memory of many persons now living.

An acquaintance with the mineral products of our own country forms no part of what is deemed a regular course of liberal education; and in general, landed proprietors, however enlightened on other subjects, know little more of their own estates below the soil and the sub-soil than their ancestors in the darkest ages of our history. Very few situations have been scientifically examined to ascertain the nature and quality of the mineral substances they contain, though such an examination could scarcely fail to reward the labour of research, and would frequently open new sources of wealth to the proprietors, and prove a public benefit by multiplying the objects on which national industry might be profitably employed The combinations in the mineral kingdom are so infinitely diversified, that scarcely two situations in the same district agree precisely in their mineral products, and even the same bed or stratum often varies greatly in its quality in different parts of its course. Instances

stances are not unfrequent of proprietors of estates purchasing from a great distance the very substances which they possessed on the surface of their own ground. A gentleman of high respectability near Bath lately informed me that for more than thirty years he had procured at a heavy expense from Wales, at the distance of one hundred miles, a particular lime-stone which cements under water, for the use of his extensive coal mines in Somersetshire. Walking one day over his estate, he picked up a stone from the projecting rocks, and was struck with its resemblance to the Welsh lime-stone: he ordered a trial to be made of it, and found it in every respect similar, and has continued to use it in his works ever since. Numerous instances of the same kind might be cited. Indeed there are few extensive estates whose value would not be greatly increased by a correct knowledge of the mineral substances they contain. The well known maxim of Lord Bacon, that *knowledge is power*, is particularly applicable to this subject; for, as Sir John Sinclair has justly stated, "a knowledge of our subterranean wealth would be the means of furnishing greater sources of opulence to the country than the acquisition of the mines of Mexico or Peru *.”

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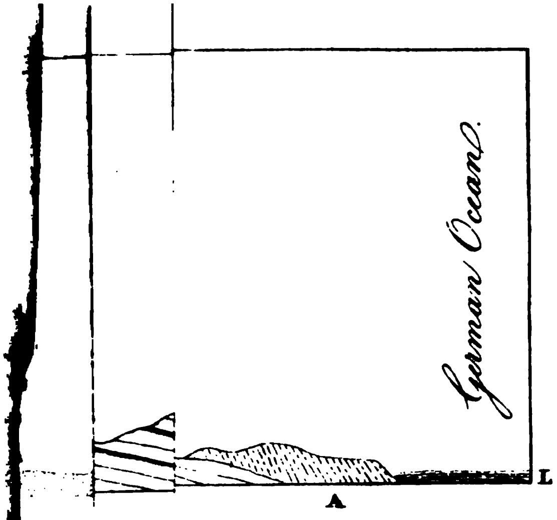
* This knowledge would frequently save landed proprietors from the expense of subterranean operations; for in numerous situations an acquaintance with the true nature of the rocks or strata on the surface would previously demonstrate that the objects of their research were unattainable.

The author trusts it will not be deemed either irrelevant or obtrusive to refer the reader to the notice prefixed to the Appendix of the present volume, explanatory of his pursuits.



h End. Bakewell.

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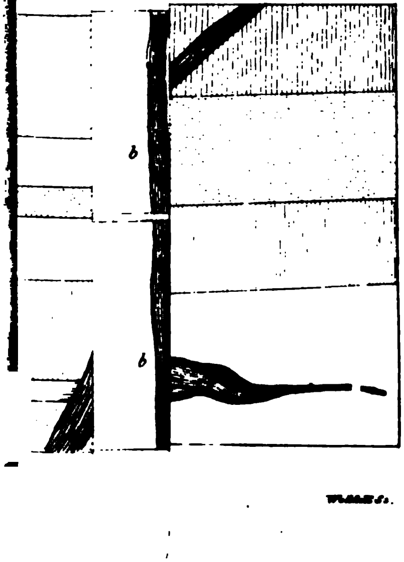

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CHAPTER XV.

On the Crystallization of Mountain Masses.—Variation of Polar Magnetism.—Geological Theories.—Formation of Planetary Bodies.—Appearance of new Stars.—Inferences and Conclusion.

THE particles of all solid bodies that can be dissolved by heat, or held in solution by fluids, have a tendency to unite when slowly cooled or evaporated, and to arrange themselves into regular forms called crystals. The Author of nature has impressed on different mineral substances determinate forms that distinguish them from each other. The laws by which the arrangement of the particles takes place to produce the various crystallizations in the mineral kingdom have been most luminously developed by the labours of the Abbé Haüy. Hitherto, however, crystallization has been considered as almost entirely confined to minute portions of matter: its effects on a large scale have not been regarded; and where they have forced themselves on the attention of the most careless observer, attempts have been made to deny their existence, or attribute to them a fortuitous origin. A more enlarged and attentive view of nature will, I believe, convince us that the laws of crystallization have extended to the great masses of matter denominated mountains, and perhaps to the nucleus of our planet itself. That the structure of many mountains considered as stratified is owing to crystallization, will, I conceive, admit of direct proof. To understand the subject more clearly, it will be necessary to begin with those rocks whose crystallization *en masse* is most discernible, I mean the basaltic rocks. When these first attracted the attention of the scientific world, various theories were advanced to account for their formation; but until the experiments of Mr. Keir and Sir James Hall had demonstrated that basalt, vitreous lava, and even glass, will assume the stony texture and crystalline form if slowly cooled from a state of fusion, the origin of basaltic columns appeared involved in much obscurity. The regularity of these columns, and the distinct articulation of the several prisms of which they are frequently composed, see *a*. plate III. figure 1.

will not allow us for a moment to suppose that they are fortuitous rents or seams, occasioned by the drying or shrinking in of the basalt. These forms are as evidently the result of crystallization as those of the crystals called garnet or the tourmaline*.

It has been before stated that basaltic and granitic rocks frequently contain globes, which consist of concentric spheres, see *D* plate III. figure 1. Sometimes these globes are radiated, in other instances the globes appear to have been compressed against each other, and their sides flattened, as in *C* fig. 1. When the compression takes place on each side equally, hexagonal prisms will be produced. Similar balls are found in the basalts of Auvergne and in various other situations. Dolomieu observed balls with diverging rays in the products of Ætna †.

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* Plate III. fig 1. *b*. is intended to represent a column, in which the projecting points seen in fig. *a*. are decomposed.

† The balls from Vesuvius which I have seen, called volcanic bombs, are evidently of a different formation, consisting of pieces of lava which had taken a globose form in the air at the time of their ejection, when in a melted and fluid state.

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In the experiment of Mr. G. Watt on melted basalt before stated, spheroids two inches in diameter were formed in the stones, which were composed of concentric radiated coats; in other instances, by the enlargement of the spheroids, the sides were compressed, and they formed prisms or polygons.

Whoever has attended impartially to the facts stated by Mr. Keir, Sir James Hall, and Mr. Watt, and has examined specimens of the products of their experiments, can scarcely doubt that the columnar and globular structure of rocks is the result of crystalline arrangement. That the slaty and tabular structure of rocks is also the result of crystallization may be less obvious, but I think is not less certain. It is stated by Ferrara, that slate brought to a state of fusion has been observed to assume the slaty structure again when slowly cooled; and it is admitted that the tendency to a slaty structure in most stones is owing to the mica they contain. Now no one will deny that the laminæ of mica are the result of the crystalline arrangement of the particles, and not of mechanical deposition; and the instances of the laminæ of slate dividing in a contrary direction to that of the tabular mass, are a clear proof of the crystalline arrangement of the rocks in which they occur. Semivitreous lava is not unfrequently divided by horizontal seams into tabular masses resembling the divisions of stratified rocks; but it will not be contended that such lava is stratified in the common acceptation of the term: nor do I think we have more reason to consider the tabular masses of granite, porphyry, or slate, as the effect of stratification. They may sometimes be the result of mechanical separation; but such partings have generally rough uneven faces, which distinguish them from those divisions which are the effects of crystalline arrangement. The tabular masses distinguishable among the columns of Cader Idris are evidently crystals: see plate V.

The tendency of unorganic matter to assume crystalline forms is so powerful, that it is in some instances able to produce this arrangement in the particles of solid bodies at a temperature much below that of fusion, and even in the common temperature of the atmosphere. In the experiments of Mr. Watt, the changes took place and the crystals

stals were formed when the stone was in a solid state, but at a high temperature. The magnetic influence of the stone, he also observes, keeps pace with the perfection of the arrangement of the particles. He further states that "instances even more remarkable have been known and authenticated, though perhaps they have not generally been regarded with the attention they deserve. Glass vessels are well known to be convertible into Reaumur's porcelain by the internal arrangement of their particles, without losing their external form, and consequently at a temperature much below that requisite for their fusion. The change of glass into Reaumur's porcelain does not arise from an evaporation of the alkali, as has been alleged, but from a regular arrangement of the molecules of the glass. It commences by the formation of fibres, perpendicular to the surface of the glass, and penetrating into it. At nearly the same time, smaller radiated globules are formed in the interior of the glass, and the union of these with the fibres, by their mutual increase, forms the whole into a new substance; and if the requisite temperature be longer maintained, the fibres disappear, and the whole becomes fine grained, and almost compact. This substance, from the improved state of its aggregation, is much stronger and more tenacious than before, and is not fusible at a heat sufficient to fuse the glass it was formed from: but if that aggregation be once destroyed, the glass resulting from its fusion is equally fusible with the original glass; and a repetition of the process will again form Reaumur's porcelain, which may be again fused, and so on repeatedly, for the quantity of alkali evaporated during the operation is extremely small. The hardness and brittleness of metals rapidly cooled, contrasted with the softness and tenacity resulting from their gradual refrigeration, are all analogous instances; and all the processes in which annealing is employed, and more remarkably the tempering of steel, are proofs of the internal motions and arrangements of the particles of matter, at temperatures very much below the heat requisite for their fluidity."

Examples of the particles of solid matter changing their mode of arrangement at the common temperature of the atmosphere are furnished by calcareous stalactites, which are formed by a successive deposition of calcareous particles over each other, producing concentric coats: these become radiated, and when broken, the arrangement appears to have taken the form of the lines in plate III. fig. 1, *d.* In a further stage of the process the radiated structure disappears, and the stalactite becomes irregularly crystalline, and at last is changed into perfect calcareous spar, which divides into regular rhomboids. All the gradations may be observed in the same specimen. Thus it appears that the particles of solid matter are capable of a certain degree of motion; and changes in the mineral kingdom may be effected when matter is apparently in a quiescent state. These changes appear to be confined to the internal structure of minerals. The external structure, or that of the mountain mass, seems to require the more powerful operation of other agents; and philosophers have long been divided in their opinion, whether primary crystalline rocks were formed by igneous fusion, or from aqueous solution. The latter opinion, supported by Werner and his disciples, has been already stated. The theory of Dr. Hutton supposes that crystalline rocks were formed from the materials of a more antient world, fused by central subterranean heat; and that secondary strata were also formed from the decayed materials of former continents, carried down by rivers and deposited at the bottom of the sea: being at a greater distance from the central heat, they were either imperfectly melted, or merely softened and consolidated without losing their stratified structure. It further supposes that our present continents were raised from the ocean by the expansive power of subterranean fire, which has bent, fractured, and separated the incumbent strata, and elevated the subjacent rocks. The parts of this theory which relate to the formation of primary and basaltic rocks by igneous fusion are consonant with many existing appearances; but it would be incompatible with the plan of the present work to enter into a detailed exposition of its merits or defects. I have already stated my opinions fully on the formation of basaltic rocks, and shall further observe that the crystalline or pyramidal forms of mountains, which so frequently excite the astonishment of the traveller in distant parts of the world, were I conceive produced by a similar mode of formation.

The experiments of Mr. G. Watt may also elucidate the cause of the variation of the magnetic needle. By the arrangement of the particles of the stony mass, they acquired a magnetic influence, which became so powerful, that fragments were capable of being suspended by the magnet: this influence kept pace with the perfection of the crystallization; and the arrangement was effected when the stone was in a solid state. From hence it appears that a different arrangement of the particles by variation of temperature is all that is required to change the magnetic state of the internal parts of the earth.

I am not aware that these highly interesting experiments were considered by Mr. G. Watt, or have subsequently been considered by others, as illustrative of the cause and variation of magnetic polarity in the earth; but it appears from them, that nothing more is wanting to give this property to matter, than such an arrangement of the particles as can even take place by change of temperature, when bodies are in a solid state. It is necessary to remark, that the iron which the basalt contained did not become more metallic by the process which produced the magnetic influence; for this was at a temperature far below fusion, and therefore could not occasion any chemical change. The existence of subterranean fire, deep under the surface of the globe, is proved by the long duration of volcanic eruptions from the same place; and we cannot suppose that the operations of this powerful agent are not regulated by the same determinate laws which govern the external universe. We are indeed unacquainted with the causes by which its activity is directed to different parts of the earth in succession, but such appears to be the fact. Now we have only to admit that there may be a certain track along which this internal fire is progressive and retrograde, and we shall have all the circumstances required for making different parts of the earth magnetic in succession, and producing a variation of magnetic polarity, which has hitherto been regarded as an inexplicable phænomenon.

On taking a view of the terrestrial globe, and observing the changes which its surface has undergone, it is scarcely possible for the imagination to restrain its activity; we are almost irresistibly led to speculate respecting its past and future condition.

All geologists are agreed on one fact, that every part of the dry land has once been covered with the ocean. It is also clearly established, that many genera and species of quadrupeds once existing have disappeared from the earth. Another fact, not less interesting, appears likewise certain, that at the period when these great changes took place man was not an inhabitant of the planet.

A state of things so different from what we now observe, and implying such long periods of past duration, we find it difficult to admit, notwithstanding the numerous proofs by which it is supported. Our ordinary ideas of time are regulated by those revolutions of the earth and moon that are completed in days, months, or years; but there are other revolutions which require multiplied ages for their accomplishment;—though the poles of the earth are sensibly moving round the poles of the ecliptic, more than twenty-six thousand years must elapse to complete one ecliptic revolution or day. This is not a matter of speculation, but a well known fact. If the different epochs or revolutions in which our planet was reduced from a chaotic state to its present habitable form be measured by these great ecliptic days, sufficient time will be allowed for the various changes and the different succession of animals which the rocks and strata that environ the globe present to our observation. It is owing to the finite powers of human comprehension that we feel any difficulty in admitting this mode of computation; for we are expressly informed on high authority, that in the divine mind "a thousand years are as one day."

In the present order of nature we observe that animals and vegetables advance by a comparatively slow progression to maturity: such appears also to have been the order of nature in the progression of our planet to a tranquil habitable state. What various reflections crowd upon the mind, if we carry back our thoughts to the time when the whole surface of the globe was agitated by tumultuous and conflicting elements; or to the succeeding intervals of repose, when all was one vast solitude; and again to a subsequent period, when the deep silence of nature was broken by the bellowings of the great mastodon* and the mammoth, who stalked the lords of the creation, and perished in the last grand revolution of the globe before the formation of man! These different stages of progression in our planet are marked by the present position of organic remains. The bones of the mastodon and mammoth are found only in the upper strata near or upon the surface; but neither in these, nor in any of the lower strata, have vestiges of human bones been discovered †. Thus, from natural appearances, from the Mosaic history,

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* The great mastodon, or the animal whose bones are found in North America near the Ohio, differs in the form of its teeth from the Siberian mammoth, and great northern elephant. In the year 1796 the body of one of the latter was detached from a mass of ice, in which it had probably remained some thousand years. The flesh was undecayed. Beside the coarse hair on the skin, there was a fine down or wool underneath, proving incontestably that it was a native of northern climates, and belonged to a race now extinct.

† I do not consider the skeleton at Guadaloupe as forming an exception. It appears to have been imbedded in loose sand on the coast, which has been subsequently consolidated. See p. 20.

tory, and from tradition, we may infer that the world is in a state of comparative infancy, if we commence our computation from the period when it became habitable by man. The little progress which improvement and civilization have made in various parts of the world may be regarded as a further proof of the recent origin of the human race. What ages may elapse before another great revolution of the globe takes place it would be rash to inquire, as we have no data to guide our conjectures. Some of its cœlestial revolutions are not accomplished in many thousand years; and in the system of which the earth forms a part, the completion of a great cycle, in which all the planets return into the same relative situations, requires ages of duration, that to our limited powers appears like eternity. That the motion of the earth in the heavens has any connection with those internal causes which produce the changes on its surface, is not proved. Such a connection may however exist; and it is possible that, if we are ever acquainted with a true theory of the earth, we shall be indebted to certain facts in astronomy for the discovery

Geologists who have speculated respecting the formation of the globe have considered it as originally in a fluid state, either by the agency of fire or water; but the simplest form of matter with which we are acquainted is that of gas or vapour. Let us for a moment consider the elements of which all terrestrial substances are composed, as existing in this simple form when the *fiat* of almighty power impressed upon the whole the various affinities by which they coalesced, and formed a fluid or solid mass. During their union, intense light and heat would probably be evolved, presenting to the distant inhabitants of the universe the appearance of a star of great brilliancy, but of short duration. Nor are facts wanting to warrant this hypothesis: the sudden concretion of stony masses in the atmosphere, with the intense light evolved during their formation, may be analogous to the production of a planet.

It is well known to astronomers, that new stars have suddenly appeared with a brilliancy exceeding that of Jupiter. These stars were stationary, but their splendour diminished, and in a few years was extinct. Such was the star seen by Tycho Brahe in 1572, and by Kepler in 1604. Nothing like them has since been observed, nor has any explanation that I know of ever been attempted. The formation of a new planet, by the sudden concretion of gas expanded over a vast space, offers I conceive a probable solution of the phænomenon. Such a concretion might produce more light than the sun, or any of the fixt stars; for, wherever chemical combination is rapidly taking place, light and heat are evolved. It would not be difficult to pursue such speculations, and to imagine this concreted matter to become cometary or planetary, or to have a succession of beds or strata produced by repeated concretions till the atmosphere alone preserved its gaseous state; nor would it require much ingenuity from such data to form a theory of the earth as consistent with existing appearances as any preceding hypotheses. In the present state of geological science, facts are more wanted than speculations. Speculations are not however to be considered as entirely useless; they serve to awaken curiosity and stimulate inquiry. It has also been regarded by the wisest of philosophers in ancient times, as a presumptive proof of the high future destiny of man, that he alone of all terrestrial animals is endowed with those powers and faculties which impel him to speculate on the past, to anticipate the future, and to extend his views and exalt his hopes "beyond this visible diurnal sphere."

CHAPTER XVI.

Queries and Observations relating to the Formation of the superficial Part of the Globe.

In the present chapter I propose to offer some remarks and queries respecting the formation of the rocks and strata that compose the superficial covering of the globe, and to state the inferences which appear to me deducible from the contemplation of existing phænomena. I beg, however, to be distinctly understood as offering these observations to the consideration of geologists, without any desire to obtain their assent, further than may be warranted by the evidence of facts, or by rational probability. Whatever may be thought of the queries here proposed, they cannot, I trust, prejudice any candid mind against the preceding parts of the volume. If philosophers, instead of fabricating hypotheses, had proposed their speculations in the form of queries, in imitation of Newton (in his Optica lib. 3), they would have rendered a more essential service to science. Thus relieved from the labour of defending their own systems, they would have been more free to follow truth wherever the light of evidence and induction might lead them. Many important discoveries might have been anticipated, which could not be brought forward as parts of a system; because the connecting links in the chain of discovery were still wanting. Such was the anticipation of the inflammable nature of the diamond, by Newton. When any science is just advancing beyond its infant state, the mode of proposing our opinions, in the form of queries, is most desirable; and I trust this will be a sufficient apology for adopting it in the following pages.

The geologist endeavours to make himself acquainted with the various beds and strata that form the crust of the globe; and, if possible, to discover by what process they were formed, as well as to trace the changes they have subsequently undergone. The power of man to penetrate the earth is very limited: few mines have been sunk to so great a depth as five hundred yards; yet by the fractures and dislocations of the strata we are frequently enabled to measure their thickness as they rise in succession to the surface over a considerable extent of country. But the regularity of rise is limited, and the strata are lost as we proceed further or incline in an opposite direction, so that the greatest aggregate thickness that has been any where examined does not perhaps exceed eight miles. The diameter of the earth is nearly eight thousand miles, to which the depth of surface that we are acquainted with bears no greater proportion than the thickness of a wafer to the diameter of a three-feet artificial globe.

Were we to bear these facts in mind, the fractures, dislocations, and overturnings of rocks and strata, and even the up-heaving of the bed of the ocean, phænomena which appear so overwhelming to the imagination, sink into comparative insignificance: instead of being astonished at these changes, we should be more disposed to admire the stability of nature, in preserving the incrustation of the globe so perfect amidst the conflict of tumultuous elements. There are a few leading facts in geology, which we may consider as clearly ascertained by existing phænomena. Among these we may enumerate, 1st, That the present continents were once covered by water. 2nd, That the strata in which organic remains occur, were formed in succession over each other. 3d, That every regular stratum was once the uppermost part of the globe. Let us further inquire, whether there remain any appearances in nature that may indicate in what manner these strata were formed, or the source from whence the matter of which they are composed was evolved. The two great agents in the decomposition and formation of mineral substances, either artificially or in nature, are water and fire: any theory which should exclude the agency of either from the formation of the crust of the globe would be manifestly defective.

The numerous volcanoes scattered over the globe abundantly prove the existence of fire in the deep recesses of the earth. During a former state of our planet, this internal fire must have been more intense than since the records of authentic history. This is shown by the remains of mighty volcanic craters, which far exceed any that are active at the present time; for, the craters themselves being formed by the eruption of volcanic matter, their size bears evidence to the magnitude of their former operations.

It is natural to inquire what part these tremendous agents have performed in the œconomy of nature: Are they accidental appendages, or essential parts of the terrestrial system? The geologists who exclude the agency of fire from the formation of rocks, seem to forget that the only instances we have of actual rock formations are volcanic: beds and strata more than thirty miles in length, and of considerable breadth and thickness, have been spread over the surface of the globe in our own times: and according to Mr. Humboldt, the further back we trace these eruptions, the greater is the similarity between the currents of lava and those rocks which are considered by geologists as the most ancient. The enormous volcanoes whose craters are many leagues in extent had doubtless an important office to perform in nature: and can it be unreasonable to believe that the earth itself is the great laboratory and storehouse where the materials that form its surface were prepared, and from whence they were thrown out upon the surface in an igneous, aqueous, or gaseous state, either as melted lava, or in aqueous solution, or in mechanical admixture with water in the form of mud, or in the comminuted state of powder or sand? Inflammable and more volatile substances may have been emitted in a gaseous state, and become concrete on the surface.

These primæval eruptions, judging from the size of the ancient craters, may have been sufficient to cover a large portion of the globe. Nor can it be deemed improbable that still larger and more ancient craters have been entirely covered by succeeding eruptions. In proportion as the formation of the surface advanced, these eruptions might decline, and, when their office was performed, might finally cease.

It is not necessary to suppose that these subterranean eruptions consisted only of lava in a state of fusion. The largest active volcanoes at present existing, throw out the different earths intermixed with water in the form of mud. Nor should we limit the eruptions of earthy matter in solution or suspension to the known volcanic craters: the vast fissures or rents which intersect the different rocks may have served for the passage of the subterranean matter rising to the surface. Silex or quartz, either pure or combined with other earths, constitutes two thirds of the crust of the globe; and the veins which intersect the lowest granitic and schistose rocks are most frequently filled with this mineral. Whether the elementary parts of silex are easily soluble in water, or fusible by fire, we have yet to learn; but we know there are natural processes by which its solution is effected, and may not the strata of crystalline sandstone have been formed from these solutions? Calcareous or cretaceous matter is also ejected during aqueous eruptions. (See page 317.) The beds of lime-stone may have been formed by similar calcareous eruptions; and the numerous remains of shell-fish in lime-stone might appear to indicate that the calcareous solutions were favourable to the growth of animals whose coverings contain so much calcareous matter. Nor is it necessary to suppose that these aqueous eruptions were always sudden, and attended with violent convulsions; for, when a passage was once opened, they may have risen slowly and been diffused in a tranquil state, and by gradual condensation may have enveloped the most delicate animals or vegetables without injuring their external form.

The long intervals of repose between the great igneous volcanic eruptions may have allowed time for the growth and decay of animals whose remains are found in different strata; whilst the formation of other strata may have taken place, under circumstances incompatible with organic existence; and accordingly we find in the rocks most abounding with organic remains, certain strata in which they never or rarely occur. The same agent which enveloped living animals in mineral matter without injuring their external form, appears in some instances to have immediately arrested the functions of vitality. Petrified fish have been discovered in solid rocks in the very attitude of seizing and swallowing their prey. A sudden eruption of a hot fluid saturated with the different earths (or the elements of which these earths are formed) might destroy in a moment the animals previously existing, and form round them a siliceous or calcareous incrustation which would protect their remains from further destruction.

Ages of tranquillity might elapse in the interval of different eruptions, and beds of gravel and breccia be formed by the gradual disintegration of the higher parts of the earth. These beds might be afterwards covered by, or intermixt with, the crystalline beds from subsequent eruptions; and may we not in this manner explain the alternation or intermixture of crystalline rocks with those of mechanical formation? Dislocations of the strata by earthquakes and other causes might also take place between the periods of different formations, in which case the upper beds would rest on the subjacent ones in an unconformable position.

As the strata which cover each other are often composed of very different mineral substances, may we not infer that the successive ancient eruptions, whether igneous or aqueous, contained different elementary parts? At the present day, the lavas of succeeding eruptions even from the same crater differ both in external character and constituent parts. Hence we may explain the formation of strata of iron-stone and beds of other metallic ores alternating with earthy strata; and we can have little difficulty in the admission, as it is now known that the bases of the earthy strata are also metallic. Two or more mineral substances may in some instances have been contained in the same fluid, and separated into different masses or strata by the laws of chemical affinity: but it seems exceedingly difficult to admit, with the Neptunian geologists, that all the substances which compose rocks and strata were coexistent in the same fluid, and that this fluid after it had deposited only a small part of its contents was capable of supporting animal life.

The succession of aqueous and igneous eruptions would account for the alternation of volcanic rocks with others of aquatic formation. The occurrence of obsidian and basalt with clay and sand-stone may be parts of the same series of phænomena; and thus the two opposing systems of Werner and Hutton may both be true to a certain extent, and agree with existing facts. However vast these operations may appear, they sink into insignificance, compared with the bulk of our planet itself. If a three-feet globe were to contain within it a fluid capable of acquiring consistence by exposure to the air, and were this fluid from time to time to exude through minute cracks or punctures, and form over different parts of the surface successive coats of varnish whose aggregate thickness was less than that of a wafer, this would be a greater change with respect to the artificial globe, than the formation of all the rocks and strata with respect to the earth. And the numerous dislocations and fractures, by subsidence or other causes, are no more in comparison to the magnitude of the earth, than the cracks or inequalities of this superficial varnish would be to a globe of that diameter.

I have already stated my opinion *, that all the secondary strata are local formations originally deposited in detached lakes, which have covered part of our present continents when the sea began to retire; for the inequalities of the surface must have been greater before the deposition of the upper strata had filled up the lower concavities. In proportion to the quantity of matter thrown from the interior of the earth might be the subsidence

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* Chapter X.

of the surface in other parts; and as the waters retired further from our present continents, the size of the lakes which then covered them would be diminished; but their number would be increased, and also the number of local, or independent, formations of strata. Similar causes still continuing to operate in different situations, might produce general features of agreement amidst the diversity of rock formations which were taking place. Now this is precisely what we observe in comparing the succession of rocks in distant countries. We have no sufficient reason to believe that those rocks which are called primitive, in reality the original coat of the nucleus of our planet, nor that the similar rocks of distant regions are contemporaneous; the great diversity which prevails both in their order of succession and composition appears to oppose the theory of universal formations, there being no two countries in which the order of succession is found to agree; and a recent examination, by Raumer, of the very district in which the Professor of Freyburg laid down the law of succession for the whole globe, is said to have shown that Werner's descriptions do not even agree with the actual order of succession in which the rocks of that district are arranged.

Granite, porphyry, sienite, green-stone and basalt pass by such insensible gradations into each other, and into rocks known to be volcanic, that the probability of their having a similar origin can scarcely be denied. And if the internal fires that have acted successively on the surface of the globe were of vast extent, as the remaining craters indicate, they may also in numerous instances have melted or softened pre-existing rocks and strata, and occasioned the bending and contortions of the strata, and other phænomena on which the theory of Dr. Hutton was founded. The defect of that theory consists, I conceive, in extending the operation of this cause further than existing appearances will support.

Were we to admit that rocks are local formations produced by successive igneous and aqueous eruptions forced through craters and fissures of the surface, these, with subsequent elevations and subsidences of the surface, might be sufficient to explain all the various phænomena which the position, contortion, succession, and alternation of rocks and strata present to our notice. In some situations granite mountains are covered with a series of schistose rocks, to which succeeds the mountain lime-stone, and on this are laid the sand-stones of the coal formation. In other instances these sand-stones rest immediately on granite, without the intervention of schistose rocks. Here then we may suppose that no eruptions of matter took place between the formation of the granite and the sand-stone; while in other situations a succession of formations had produced all the intermediate rocks. In some countries the eruption of matter which formed granite, after ceasing for ages had again taken place, and thus sometimes we find granite covering rocks to which it is most frequently subjacent. To a like cause may we ascribe the occasional appearance of beds similar to the lower rocks alternating with or appearing in the upper strata. The siliceous and calcareous solutions in a state of tranquillity might also envelop the fragments and sand from pre-existing rocks, and form the various breccias and aggregated sand-stones. Saline and bituminous matter may also have been thrown up in detached lakes, and subsequently consolidated, as in the pitch-lake in the Island of Trinidad. The local formation of beds of trap alternating with other rocks has before been alluded to, and the graduation of basalt into clay, or sand, will be consistent with this mode of formation. Many of the solutions containing terrene matter might be erupted at a boiling temperature, like the siliceous water thrown out of the hot springs in Iceland, and on cooling they might deposit their contents, the matter from each eruption forming a separate layer or stratum*.

In some parts of the earth the quantity of matter thrown out during one eruption may have been sufficiently great to admit the crystallization of whole groups of mountains. In other instances it may have been so widely diffused as to form very thin strata. And

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* To compare great things with small, there is an analogous formation taking place every day in the channels which receive the boiling waters from some of the steam-engines in the county of Durham. This water contains a large quantity of earthy matter which is deposited every day, except Sunday, in regular layers that may be distinctly counted, with a marked line for the interval of repose on Sunday, between each week's formation: hence the stone got out of these channels has received from the country people the name of *Sunday stone.*

here

here it may be proper to remark, that different beds and strata are not arranged in nature in the order of their specific gravity; the lowest are not always the heaviest, neither are they arranged according to their more perfect crystallization; for, though generally the lower rocks are more crystalline than the upper, we not unfrequently find some of the upper strata more perfectly crystalline than the subjacent rocks. Now if the matter of which the upper and lower rocks are formed had been co-existent in the same fluid medium, one or other of the above effects must have taken place; but if each stratum were formed by a separate eruption and deposition, they might vary both in specific gravity and degrees of crystallization, without any regard to the order in which they were deposited*.

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* By considering each stratum as a local formation, we are relieved from the difficulty of accounting for the disappearance of the vast beds of sand-stone and chalk, with all the upper strata, in countries where they are not found at present. Could we be presented with an accurate delineation of the elevations and depressions of the earth's surface, sufficient vestiges of its ancient physical geography might still remain to enable us to trace some of the great basins, or lakes, in which the separate formations of the upper strata took place.

In endeavouring to trace the causes of very complicated phænomena, those explanations are to be preferred which apply to the greatest number of cases, and are consonant with existing or analogous facts. Now I conceive that the alternation of aqueous and igneous eruptions offers a more satisfactory explanation of the formation of rocks than any that I am acquainted with. At the same time it assigns an office to the immense craters and fractures which have once perforated or intersected the globe.

It is an acknowledged maxim, that Nature, or to speak more correctly its divine Author, does nothing in vain; and can we suppose that the interior part of the earth is constructed with less skill than what we observe in the organization of the simplest animal or vegetable? Or, when we contemplate our planet pursuing its trackless path through the heavens with unerring precision, can we believe that its internal motions are not governed by determined laws destined to answer the most important purposes in the œconomy of nature?

Though I am inclined to regard the explanation here offered respecting rock formations as consonant with existing facts, and as reconciling the phænomena of aqueous and igneous products alternating with or graduating into each other,—facts that appear so contradictory to the theories hitherto advanced,—I would, however, willingly adopt any other explanation that may afford a more satisfactory solution.—The Roman Poet, after conducting his hero through the subterranean abodes, dismisses him through the Ivory Gate*: and should my readers infer from these speculations respecting the subterranean operations of nature, that I take my leave of them in the same manner, it will neither cause disappointment nor excite displeasure. Embarked with them in a voyage of discovery, I shall gladly hail the signal for the appearance of solid ground, whoever the fortunate discoverer may be.

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* Æn. lib. vi.

THE AUTHOR'S NOTICE TO LANDED PROPRIETORS.

Mr. Bakewell informs those noblemen and gentlemen who may honour this volume with their perusal, that he undertakes the mineralogical examination of estates to ascertain the true nature and qualities of the soil, stone, and various minerals or metallic ores, and the uses to which they may be most profitably applied; also to point out the means of general improvement. A manuscript description and statistical account of the estate with explanatory outlines and sections will be given, arranged in such a manner that it may at any time be consulted as a book of reference when information is wanted respecting the property. Such a description will prove particularly useful to landed proprietors who have large or distant domains, by enabling them to form a correct view of the nature and value of their estates; it will also comprise an account of whatever may be deemed interesting as objects of curiosity, natural history, or science, as well as those of profitable research.

An examination and description of estates upon the above plan is new; but its utility is obvious, and Mr. Bakewell can give references of the highest respectability where he has been employed. The expense must be regulated by the nature and extent of the estate; and it is believed that the terms will be found in all cases very moderate, compared with the benefits to be derived from such an examination. To remove any objection on this head, the amount of the charge may be previously specified for the execution of the whole or any part of this undertaking.

When in town Mr. Bakewell gives private instruction to direct gentlemen in a course of experimental researches on agricultural chemistry, mineralogy, and other subjects of science connected with his pursuits.

Letters free of postage addressed to Mr. Bakewell, 13, Tavistock Street, Bedford Square, London; or left for him at Mr Harding's, 36, St. James's Street, will be duly attended to.

APPENDIX.

ADDITIONAL NOTES.

Note on page 5.

THE *absolute quantity of matter, or density of the earth.*] Besides the observations to ascertain the density of the earth by Dr. Maskelyne and Dr. Hutton, a very ingenious instrument was invented by the Rev. J. Mitchell to determine this important problem. He did not live to carry it into effect; but it was afterwards executed by Mr. Cavendish. See Phil. Trans. 1792, part ii.

Doctors Maskelyne and Hutton estimated the specific gravity of the stones forming the mountain Schehallien below their true average weight as determined by experiment, when this error was corrected by Professor Playfair. The result by the two methods may be said nearly to correspond, Dr. Maskelyne making the density of the earth about 5, and Mr. Cavendish 5.48.

Note on page 16.

The bones of the Mastodon, Hippopotamus, and other quadrupeds found in England have generally been in low situations and in alluvial ground. We have no regular strata containing fossil remains of quadrupeds like those in the gypsum quarries near Paris.

Note on page 20.

The sand-stone which contained the imbedded female skeleton from Guadaloupe, was observed by the workmen who chiselled away part of the stone, to be considerably harder where it was contiguous to the bone. A similar variation in the hardness of stone, in the immediate contiguity of organic remains, may be observed in the alum rocks at Whitby, and in various other situations: it is probably occasioned by the animal matter intermixed with the stone.

Note on page 30.

Stratified rocks formed by the motion of water.] Some of the strata are evidently of mechanical formation, containing rounded pebbles and water-worn fragments of stone; but many of the strata called secondary are crystalline, and cannot be considered as mechanical depositions.

Note on page 44.

The classification of simple minerals into families, comprising in each the substances most nearly allied, appears to be the arrangement best suited to assist the memory of the student. It has been very judiciously adopted by Mr. Kœnig in the collection of minerals exhibited at the British Museum.

Note on page 111.

Red sand-stone.] The followers of Werner designate what they call the first of the flœtz rocks the "old red sand-stone." The colour of rocks is a very imperfect distinctive character. In all formations of sand-stone there are coloured strata red, and some of the beds in the red sand-stone are a light brown or gray. The red sand-stone which stretches along the western side of England in many parts agrees with the red sand-stone of Werner containing gypsum:—there are, however, many beds of red sand-stone, part of the regular coal strata of Lancashire.

On the authority of Mr. Westgarth Forster, and others, from whom I have made particular inquiry, I have stated that the metalliferous lime-stone of Northumberland and Durham rests on the red sand-stone. I have never seen their junction in the northern counties, and I am still inclined to doubt whether this sand-stone be really subjacent to lime-stone. In the first edition, and in a paper on the Bradford coal-field*, I intimated the probability that the red sand-stone might have been formed from the debris of the thick beds of sand-stone that lie above the metalliferous lime-stone, and had once extended further west. This rock always occurs at a low comparative level, which adds probability to the opinion that it may lie at the feet of the western hills in an unconformable position, instead of rising from under them as a regular lower stratum. There are however beds of sand-stone, which are sometimes red, both under metalliferous lime-stone and coarse slate:—an instance of their junction is stated p. 388. I consider the real position of this rock as more uncertain than that of any other considerable rock formation in England.

Mr. Farey, in his Derbyshire, mentions the red marle on the eastern side of England as the same with the red sand-stone on the west, and describes it as a stratum above the coal measures. He has recently adopted the opinion that the red marle is generally laid in an unconformable manner over the edges of the strata beneath, and that it occurs covering both coal and the rocks subjacent to coal strata. If the red marle in Nottinghamshire, and the red sand-stone in Cheshire, were both regular strata, it would be impossible, I conceive, to admit their identity; but if they are unconformable depositions, there can be no objection to this admission, provided that their other features of resemblance warrant the conclusion. There are quartz pebbles in some of the sand-stones of Cheshire, similar to those in the sand-stone rock on which Nottingham and the castle are built.

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* Geological Transactions, vol. ii.

Note on page 169.

On the banks of the river Missouri.] From the Travels of Captains Lewis and Clark it does not appear that there is sufficient evidence for the existence of the chain of mountains of rock salt here alluded to. These travellers mention a vast extent of country beyond the Missouri covered in part with salt lying on the ground like snow.

Note on page 212.

There appear to be processes in nature by which flint is forming at the present time. Instances are on record of coins found in flints. (Kirwan's Geological Essays.)—The following circumstance was obligingly communicated when the first edition of this work was in the press:—"In 1791, 200 yards north of the ramparts of Hamburgh, in a sandy soil, Mr. Liesky, of that city, picked up a flint, and knocking it against another to obtain a piece for striking a light, he broke it in two. In the centre of the fracture he observed an antient brass pin; and on picking up the other half he found the corresponding mould of the pin so laid bare: he presented them to Thomas Blacker, Esq. in whose possession they now are, and who has shown them to the writer of this paper.

"*Surry Institution.* KNIGHT SPENCER."

We are not able by artificial means to dissolve silex in water; but from the siliceous earth held in solution by the hot waters of Bath, and still more abundantly by the boiling waters of Iceland, we know that nature has the power of effecting it by some unknown process. Whether the earths are convertible into each other by natural processes, we cannot ascertain; but as they are known to consist of oxygen combined with metallic bases, and these bases are supposed to be compounds of simpler elements, it does not appear improbable that this change may take place: could the fact be established, many anomalous appearances in the mineral kingdom would admit of an easy explanation. From the qualities of barytes and the alkaline earths, Lavoisier was induced to believe that they are metallic oxyds. In the year 1805, an opinion of Mr. Joseph Hume was advanced in Mr. Parkes's Chemical Catechism, that silex is chiefly composed of oxygen. In the 33d volume of the Philosophical Magazine Mr. Hume, with much ingenuity of argument, and by a statement of various facts, endeavoured to prove that silex, in its combinations with other substances, acts either as oxygen or as a powerful acid. In the union of silex with the alkalies to form glass, we have, he observes, a striking example of its action as an acidifying principle.

Berzelius in his Mineralogy has recently adopted the same views respecting the action of silex in its union with mineral substances, and denominates such combinations siliciates.

The discoveries of Sir H. Davy have proved that oxygen is a constituent part of the earths and alkalies, and cannot fail eventually to elucidate some of the most important questions in geology.

Note on page 292.

The zoophytes in the lower beds could not be living and co-existent with the shellfish in the upper strata. It is not here intended to express any opinion respecting the priority of one species of animals to another; for in fact the upper beds of lime-stone in Derbyshire are filled with encrinites. What is contended for, is merely that the lower animals must have existed in a living state long before the formation of the upper strata by which they are covered, that contain animals of other species. We cannot surely admit for a moment that marine animals could live and propagate buried in and under solid rocks; yet we must admit this absurdity if we agree with Professor Jameson, that the upper and lower beds of metalliferous limestone in Derbyshire were cotemporaneous. An opinion was lately advanced by a German professor, that the fossil remains in rocks are not in reality the relics of living animals, but the first crude and imperfect efforts of nature to create organized forms! and some recent attempts have been made in this country to prove that shell fish live and breed in lofty peat mosses! Thus we have once more to fear

> " ——— grave ne rediret
> Sæculum Pyrrhæ nova monstra questæ;
> Omne cum Proteus pecus egit altos
> Visere montes."

Note on page 311.

Earthquakes. Confined vapour forcing a passage.] An impetuous roaring wind accompanied the dreadful earthquakes in Sicily in 1783.

Note on page 345.

Fresh-water shells.] Though, in compliance with the opinions of some eminent naturalists and geologists, I have retained the term fresh-water shells and formations, I think the fact of their being really such, rests on too slight a foundation. We know so little of the habitudes of these animals, that we can scarcely decide whether they lived in fresh or salt water; and the following circumstance communicated to me by Mr. Leckie may show that animals have greater facilities of change than naturalists generally suppose.

The lake of Lentini in Sicily is stocked with a sea fish called the Cefalo, a species of mullet caught in the Mediterranean, and thrown into the fresh water of the lake, where they not only live, but increase greatly in size and improve in flavour, and are a considerable article of luxury in the island. This lake has no communication with the sea, and is chiefly filled with rain water.

Note on page 351.

Though coal strata rarely if ever terminate in what colliers call the deep, or dip; yet we know that the strata, after declining to a certain depth, frequently rise in an opposite direction; the edges of the strata may thus be hid by rocks of another formation, and the strata may terminate at no great distance from their present known extent.

Note on page 353.

Magnesian lime-stone of Durham.] The following account of the lime-stone of this district is extracted from a paper I published on the Geology of Northumberland and Durham, in the Philosophical Magazine for February 1815:

" The Sunderland lime-stone formation extends along the coast north of the Tyne, but not in a continued line. The whole thickness of this lime-stone has not been measured; nor would it be easy to ascertain it, as some of the rocks are very indistinctly stratified. I think it cannot be less than one hundred and fifty yards. Two hills on the west of Sunderland, containing numerous marine organic remains, I am inclined to consider as of subsequent formation.

"The lime-stone of Building Hill near Sunderland and at Fulwell is particularly deserving notice, from the remarkable configurations which it presents.

"The beds at the former place are of considerable thickness: the lime-stone is imperfectly crystalline, is of a yellowish-brown colour, and yields a fœtid smell when struck with a hammer, being that species called by mineralogists swine-stone. It contains nearly the same proportion of magnesia as that of Breedon in Leicestershire, first analysed by Mr. Tennant.

"The lime-stone in some of the beds is divided into small cells uniting with each other, and pretty regularly arranged: this has received the appellation of honeycomb lime-stone, a name which conveys a tolerably correct idea of its appearance. A superficial observer might suppose from the form that this was the organic remains of some species of madrepores; but it is evidently the result of a tendency to crystalline arrangement. This arrangement has proceeded still further, and disposed distinct masses of the honeycomb lime-stone to assume determinate forms in the substance of the rock itself. The crystallization of some of these masses appears to have diverged from a centre laterally, until the radii were met by those of other diverging masses, and both became compressed on the sides. The most striking of these forms nearly resembles a papal mitre: they are from six to nine inches in length or more, and may be detached from the rock. Several of these mitre-shaped masses appear also to have come in contact during their formation, and to be compressed at the place of junction, the convexity of the one having formed a concavity in the sides of the other. We must either admit, with the late Mr. Gregory Watt, that a crystalline arrangement of the particles can take place in solid bodies at the common temperature of the earth, or that these rocks have been softened by heat, or some other cause, subsequently to their formation. Nor will even the latter opinion, I conceive, be very improbable; for on the elevated ground at a little distance to the north-west of Building Hill, I observed immense blocks of extremely hard and very black basalt lying on the surface of a ploughed field. On inquiry, the men who were working in the field informed me that numerous blocks of the same kind were buried under the soil, which impeded their operations in ploughing so much, that, when they were too large to be removed, they were obliged to break them by blasting with gunpowder. I therefore think it extremely probable, that an immense whin dyke has intersected this formation of limestone. The quarry at Fulwell is close by the turnpike road to Newcastle, and about two miles from Sunderland. The lime-stone here presents little of the honeycomb appearance of that at Building Hill; but it is not the less remarkable: it is covered by a stratum of calcareous marle, or rather sand; some of the beds are also divided by the same pulverulent marle or calcareous sand, in which are imbedded numerous detached spheres, spheroids, and also botryoidal and stalactitical masses of lime-stone: but the latter are attached to the rock. The upper stratum of calcareous sand also contains numerous balls and clusters of balls of a similar kind, varying in size from that of a pea to ten or twelve inches in diameter. That these balls are not water-worn is most evident: many of them have a crystalline diverging radiated structure, others are curvedly lamellar. The most striking circumstance attending these balls remains to be noticed: many of them appear to have come in contact at a certain stage of their formation: they present the appearance of two or more balls with a segment cut from each, and closely united at the place of section; in other instances a number of balls appear to have pressed laterally on each other and flattened the sides, thus forming polyhedral prisms convex at their upper and lower extremities. This singular conformation had not escaped the attention of that sagacious young philosopher the late Mr. G. Watt. It is indeed a fact analogous to what took place in the experiment he made by melting seven cwt. of basalt, and suffering it to cool slowly. A number of small globules formed in the mass, and enlarged till they compressed each other into a prismatic shape. The formation of these balls of lime-stone in the soft strata of this rock might probably throw some light on the globular and columnar structure common to many rock formations, were the various phænomena carefully noticed.

Note on page 353.

The first distinct account of the succession of the beds and strata above and below the chalk formation on the eastern side of England, was published by Mr. John Farey, in the first volume of his Agricultural Report of Derbyshire, page 111. Mr. Farey on this and on several other occasions has stated himself to have been a pupil of Mr. William Smith of Mitford, near Bath. According to Mr. Farey, Mr. Smith had the peculiar merit of having ascertained, "First, the practicability of tracing the basset edges of the strata in continuous lines, and delineating them in maps: Secondly, that alluvia, properly so called, are always the uppermost; and showing how to distinguish such alluvia from regular strata; and Thirdly, in the discovery that certain species of organic remains are peculiar to certain strata in the British series." In confirmation of which he formed a large collection of fossils, marking their localities carefully, to identify the different strata. I am not aware that Mr. Smith has published any account of his own labours, and it is only from his pupil Mr. Farey that we are made acquainted with them. This is the more to be regretted, as the novelty and interest which would have attached to them a few years since is in some degree passed by, in consequence of similar discoveries, by the celebrated naturalist Cuvier, having been published already through Europe. It is, however, but justice to our own countryman to state, that Mr. Smith had ascertained the important geological fact, that certain organic remains are confined to particular strata, and serve to identify them, before Cuvier had commenced his labours in this new field of inquiry.

It may perhaps be doubted whether the existence of organic remains is sufficient to identify strata in distant parts of the globe, as similar remains are sometimes found in rocks which have very little resemblance to each other: on which account I am inclined to believe that this position, like many others which have been advanced in geology, must be taken with certain limitations: indeed, were we to admit that any one stratum ever extended from the arctic circle to the equator, it seems more than probable that the animals which lived upon it must have been very different in different latitudes.

Mr. Farey's Description of the Upper Series of the British Strata.

"The highest known stratum (except the gravels and alluvia) which appears in England, and from beneath which all its other regular strata basset or emerge in succession, is a sand which occupies Bagshot Heath and a large district

strict S. and W. of Esher in Surrey, of which sand numerous other patches are to be found in the south and eastern counties, as far north as Holderness in Yorkshire.

The next in succession has been called the London clay, which is indeed a large assemblage of blue and reddish clay strata, with beds of sand and of small chert nodules interposed. Numerous deep wells have within the last twenty years been sunk through it, in London and every part of its vicinity. The *ludi Helmontii*, or clay-balls of which Parker's Roman cement, of such great use in water-works and in stuccoing buildings in imitation of stone, is made, is a product of the London clay.

A sand stratum of very variable thickness next succeeds, and lies immediately upon the chalk in most instances, as between Greenwich and Woolwich on the banks of the Thames, which has often been called the Blackheath sand: it frequently has a bed of cherty sand-stone in it called the Grey-weathers.

The upper or flinty chalk is a thick stratum of soft or free chalk, with numerous layers of flint nodules, and great variety of echini and other organized remains. The extremities of this stratum are to be found with us in the Isle of Wight in Hampshire, and at Flamborough Head in Yorkshire.

The lower or hard chalk is without flints; its beds increase in hardness until near the bottom, where a white free-stone is dug, as at Totternhoe in Bedfordshire and numerous other places: that brought from near Ryegate and elsewhere on this stratum south of London, is used as a fire-stone.

The chalk marl next succeeds, which varies much in its appearance, sometimes resembling chalk when first exposed, in other places appearing as a blue clay.

The Aylesbury lime-stone strata with green sand-beds are remarkable for their large cornua ammonis, numerous horse-head muscles, entrochi, and other shells, glossopetræ, &c. Sand strata succeed, and several clays which have no very decided character, except one of them, which contains a thin bed of dark-coloured limestone, almost entirely composed of small turbinated shells called Sussex marble, of which the slender pillars in Westminster Abbey and most of our cathedrals are made.

The next characteristic stratum, owing to its forming a ridge of conspicuous hills through the country, is the Woburn sand; a thick ferruginous stratum, which below its middle contains a stratum of fuller's earth, which is the thickest and most pure in Aspley, and at Hogstye-end, two miles N.W. of Woburn, of any known place: the upper parts of this sand are frequently cemented by the oxidated iron into car-stone, and the lower parts contain fragments of silicified wood.

The clunch-clay succeeds. It is generally blue, or inclining to black, and is of great thickness. It has towards its top several beds of clunch, a soft chalk-like stone in appearance, whence the name: numerous large gryphites and small pointed belemnites, cornua ammonis, selenite, &c. are found above the clunch; the lower part frequently contains beds of bituminous shale or clay. The vale of Bedford, the fens of Cambridgeshire, Lincolnshire and Yorkshire, are almost entirely situated upon the great planes formed by the gradual endings or feathering-out of this stratum. The Bedford limestone succeeds: it has blue clay beds interposed, and abounds with small gryphites and other shells: Buckingham, Stoney-Stratford, Newport-Pagnel, and Bedford, stand upon this stratum.

A thick clay succeeds; and then the famous ragstone of

Barnack and numerous other places, composed almost entirely of minute shells and small fragments of shells, whence the stones were dug for many of the most ancient and perfectly preserved churches and ancient buildings in the eastern counties.

The limestone and gray slate strata of Stonesfield, Colly-Weston, and numerous other places, next succeed; and abound with bones, glossopetræ, and other organic remains; and then, a sand stratum.

The Bath free-stone strata next succeed, and form a most characteristic range through England, from the Isle of Portland[*] in Dorsetshire to the Humber in Yorkshire: Stamford, Ancaster, and Lincoln, are upon this stratum, in its range to the eastward of Derbyshire. The upper part is generally a white or light gray lime-stone; then the ova-formed lime-stone or oalite of Bath, Ketton, &c. succeeds; below which is a great thickness of light-yellow free-stone, which abounds with curious shells and fossils. Below this a sand and clays occur; and then the free-stone of so many hues of yellow and red, which is dug near Northampton and numerous other places on this range.

A number and great thickness of sands and clays succeed, which admit of no precise or characteristic description in so brief an account as this is intended to be.

The Maidwell lime-stone[*] or blue marl-stone (so called by Mr. Smith from the matter in which it is imbedded) succeeds; and then other clays, which are succeeded by

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[*] Mr. Farey has since stated his opinion, that the Portland and St. Alban's Head oolite limestone does not belong to the Bath strata; but to those of Aylesbury. Phil. Mag. vol. xxxix. p. 94.

[†] Mr. Bevan, having examined the vicinity of Maidstone, is said to refer the lime-stone resting on sand to the lower part of the Northampton stone.

The lias clay. This stratum is of considerable thickness, forming generally a light-yellow tenacious surface, cold, and much disposed to ant-hills when laid down in pasture. A part of this stratum approaches within three or four miles of Derbyshire, which has enabled me to introduce it in the Map of strata and soils facing page 97*. It is there distinguished by a blue colour, through a part of Leicestershire and Nottinghamshire, from Wigstead to Cotgrave. This clay is rendered remarkable by a lime-stone in thin blue beds, called blue lias, which it contains; two or three of which beds make a lime which is superior to any other that is known, for sluices, locks, piers, and other water-works, on account of its property of setting almost immediately, even under sea water, and continuing to harden. Watchet and Aberthaw, on opposite sides of the Bristol Channel, Southam in Warwickshire, and Barrow on Soar, are particularly famed for this lime, and which probably might be had as good at numerous other places throughout the long range of this stratum, extending from one sea to another without much interruption, I believe, if the same judgement and care were used in selecting the beds most proper for water lime, instead of burning together the whole of what they dig, without selection or discrimination, as is too commonly done at lime-kilns.

The blue lias is remarkable, owing to the pentacrinus, the bones, scaly fish, and other fossil remains which it produces throughout its whole extent; and it has on the whole, perhaps, the best marked and most important geological characters of any stratum in the British series.

In the lower part of the lias clay a great succession of other lime-stone beds often occur, called white lias; but at Barrow on Soar and other places they appear only as a whitish marl, in the banks of the river and elsewhere, mouldering with the weather.

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* Derbyshire Report

From subsequent observations it appears the lias limestone does not exist in one continuous range north of the Humber, though detached portions of it occasionally occur.

A sand terminates this series, which appears at Balderton near Newark." After this, Mr. Farey describes the red marl as forming a regular stratum, which he seems to consider as identical with the red sand-stone: but Mr. F. has since admitted that the red marl is in general unconformably laid over the coal measures; and other subjacent strata.—See Phil. Mag. vol. xliii. p. 330; and vol. xlv. p. 167 and 170.

Note on page 375.

A section across this part of our Island.] The section given plate VII. fig. 1, is intended to represent the succession and arrangement of the different rock formations, without attempting more than a general resemblance to the surface outline. The elevation of the hills compared with the base is necessarily represented considerably greater than the true proportion, for the sake of distinctness. Had the true proportion been preserved, the height of Skiddaw or Sca-fell would not be more than the one hundred and fiftieth part of the base line.

Note on page 386.

Pule moss-tunnel.] "About 240 yards from the entrance of the hill, and eighty yards beneath the surface, the workmen discovered a fault or throw of the strata, which was filled with shale reared on the edge, mixed with softer earth, and in some places with lumps of coal. As the workmen proceeded with the excavation, which is nearly four yards wide, the fault for about forty yards occupied by degrees more of the space of the tunnel; at about five feet from its southern margin it contained a rib of limestone near four feet in thickness at the bottom, but not quite so thick at the top of the tunnel; on each side of the rib it contained balls of limestone promiscuously scattered, from an ounce to 100lbs. weight. The workmen have pursued the tunnel 350 yards from the entrance, and the ribs and balls of lime-stone continue the same. The limestone of the rib is not perfectly pure, that of the balls less, but makes a good lime for cement: though the surface of the country is rocky, it does not discover lime-stone any where within twenty miles; yet if the strata in Derbyshire and near Clithero be examined, it will appear probable that the base of these hills is lime-stone."—*Phil. Trans.* 1796.

I am inclined to believe the lumps of coal were indurated bitumen, from some specimens collected at the top of Stanedge, a neigbouring hill. The balls appear to contain a considerable portion of calcareous earth, united with iron-clay, and can scarcely be denominated lime-stone. The stone from the rib described as lime-stone, I had no opportunity of examining; it was all consumed or removed. In some of the collieries to the east of this tunnel, near Huddersfield, round balls were also found containing shells filled with liquid bitumen.

Note on page 451.

I am far from considering the rocks, after their first formation, as being in a state of profound repose: new arrangements, occasioned by variation of temperature or other causes, might take place among the particles themselves,

selves, as explained in the preceding chapter; for numerous circumstances lead us to infer that processes are still going on in the recesses of the earth, without the immediate aid of volcanic fires. The explosions which are sometimes heard in mountains not volcanic, (see Travels of Captains Lewis and Clark,) and the ejection of masses filled with crystalline matter recorded by numerous travellers, are at present too imperfectly known to warrant any conclusions; but they seem to indicate the present active state of the interior part of the globe.

Height of some of the most remarkable Mountains and Hills in England and Wales.

[The following admeasurements of the English and Welch mountains are extracted from the valuable 'Trigonometrical Survey' begun by Major-general Roy and completed by Lieutenant-colonel Mudge: a work which will remain a lasting monument of the ability, accuracy, and persevering application of its authors, and do honour to the reign in which it was undertaken.]

	Feet.
Allington Knoll, Kent	329
Arbury Hill, Northamptonshire	804
Arran Fowddy, Merionethshire	2955
Arrenig, Merionethshire	2809
Axedge, Derbyshire	1751
Bagshot Heath, Surrey	463
Barstead, Surrey	576
Bar Beacon, Staffordshire	653
Beacon Hill, Wiltshire	690
Beacons, Brecknockshire	2862
Bardon Hill, Leicestershire	853
Beachy Head, Sussex	564
Beeston Castle, (Top of) Cheshire	556
Black Comb, Cumberland	1919
Black Down, Dorsetshire	817
Black Hambleton Down, Yorkshire	1246
Bleasdale Forest, Lancashire	1709
Boulsworth Hill, Lancashire	1689
Botley Hill, Surrey	880
Bow Fell, Cumberland	2911
Bow Hill, Sussex	702
Bradley Knoll, Somersetshire	973
Broadway Beacon, Glocestershire	1086
Brown Clee Hill, Shropshire	1805

Cader

	Feet.
Cader Ferwyn, Merionethshire	2563
Cader Idris, Merionethshire	2914
Caermarthen Vau, Caermarthenshire	2596
Calf Hill, Westmoreland	2188
Cam Fell, Yorkshire	2245
Capellante, Brecknockshire	2394
Carnedd David, Caernarvonshire	3427
Carnedd Llewellyn, Caernarvonshire	3469
Carraton Hill, Cornwall	1208
Castle Ring, Staffordshire	715
Cheviot, Northumberland	2658
Collier Law, Durham	1678
Coniston Fell	2577
Cradle Mountain, Brecknockshire	2545
Cross Fell, Cumberland	2901
Crowborough Beacon, Sussex	804
Dean Hill, Hampshire	539
Ditchling Beacon, Sussex	858
Dover Castle, Kent	469
Dundry Beacon, Somersetshire	1668
Dunnose, Isle of Wight	792
Dwggan near Builth, Brecknockshire	2071
Epwell Hill, Oxford	836
Fairlight Down, Sussex	599
Farley Down (near Bath), Glocestershire	700
Firle Beacon, Sussex	820
Folkstone Turnpike, Kent	575
Frant Steeple (Top) Sussex	659
Furland (near Dartmouth) Devonshire	589

	Feet.
Garreg Mountain, Flintshire	835
Garth (The) Glamorganshire	981
Grasmere Fell, Cumberland	2756
Greenwich Observatory, Kent	214
Hathersedge, Derbyshire	1377
Hedgehope, Northumberland	2347
Helvellin, Cumberland	3055
Hensbarrow Beacon, Cornwall	1034
Highclere Beacon, Hampshire	900
High Pike, Cumberland	2101
Holland Hill, Nottingham	487
Holme Moss, Derbyshire	1859
Holy-Head Mountain, Anglesea	709
Ingleborough Hill, Yorkshire	2361
Inkpin Beacon, Hampshire	1011
Kilhope Law	2196
Kit Hill, Cornwall	1067
Leith Hill, Surrey	993
Lillyhoe, Hertfordshire	664
Landinan Mountain, Montgomery	1898
Llanelian Mountain, Denbighshire	1110
Llangeinor Mountain, Glamorganshire	1859
Long Mount Forest, Shropshire	1674
Long Mountain, Montgomery	1330
Lord's Seat, Derbyshire	1715
Malvern Hill, Worcestershire	1444
Moel Fammau, Denbighshire	1845
Moel Morwith, Denbighshire	1767
Mow Copt, Cheshire	1091

Nine

	Feet.	
Nine Standards, Westmoreland	2136	
Orpit Heights, Derbyshire	980	
Pendle Hill, Lancashire	1803	
Pengaen, Merionethshire	1510	
Penmaen Maur, Caernarvonshire	1540	
Pennigent Hill, Yorkshire	2270	
Pillar, Cumberland	2893	
Plynlimmon Mountain, Cardiganshire	2463	
Radnor Forest, Radnorshire	2163	
Rivel Mountain, Caernarvonshire	1866	
Rivington Hill, Lancashire	1545	
Rodney's Pillar (Base of) Montgomery	1199	
Rooks Hill, Sussex,	702	
Roseberry Topping, Yorkshire	1022	
Rumbles Moor, Yorkshire	1308	
Saddleback, Cumberland	2787	
Sea Fell (Low Point), Cumberland	3092	
Sea Fell (High Point), Cumberland	3166	
Sherwood Forest, Nottinghamshire	600	
Shooters Hill, Kent	446	
Shunnor Fell, Yorkshire	2329	
Skiddaw, Cumberland	3022	3076 ft
Snea Fell, Isle of Man	2004	
Snowdon, Caernarvonshire	3571	
Stow Hill, Herefordshire	1417	
Stow on the Wold, Glocestershire	883	
Tregarron Down, Cardiganshire	1747	
Trelleg Beacon, Monmouthshire	1011	

Water

	Feet.
Water Cragg, Yorkshire	2186
Weaver Hill, Staffordshire	1154
Wendover Down, Buckinghamshire	905
Whernside, (in Ingleton Fells) Yorkshire	2384
Whernside, (in Kettlewell Dale) Yorkshire	2263
White Horse Hill, Berkshire	893
Wittle Hill, Lancashire	1614
Wrekin, Shropshire	1320

Mountains in Scotland.

Of the height of the mountains in North Britain, I believe there have not hitherto been any very accurate admeasurements taken. The following are some of the most considerable, with the heights as given by different writers.

	Feet.
Arthur's seat Edinburgh.	810
Salisbury Craigs	550
Hartfell, Dumfrieshire supposed by Mr. Jameson the highest in the south of Scotland.	3304 or 2800,
Goatfield, Island of Arran	2945
Benlomond, Stirlingshire	3262
Benlawers, Perthshire	4051
Ben Mere, Perthshire	3870
Schehallien	3281 or 3564
The most southern of the Paps of Jura	2359
Mount Battock, Kincardineshire	3450
Ben-Nevis, Invernesshire the highest mountain in Great Britain.	4380,
Cairngorum	4050

Remarkable Mountains in various Parts of the World.

In the Alps.	Feet.
Mont Blanc	15680
Mont Rosa	15555
Buet	10112
St. Gothard	9075
Hospice of Great St. Bernard	8040
Ortler Spitze, Tyrol	15430

Various mountains in these chains rise from six to nine thousand feet. Few of the mountains north of the Alps rise six thousand feet above the level of the sea; but some of the summits of the Doffrene Hills, which separate Norway from Sweden, rather exceed that height. Mont d'Or and Cantal, in the district of Auvergne in France, are above six thousand. The highest peaks of the Pyrenees rise from six to ten thousand feet above the sea. Vigne Marle, the loftiest summit in this chain, is ten thousand and sixty-eight feet.

Italy and Sicily.	Feet.
Mount Etna (doubtful)	10963
Vesuvius	3900

Of Africa the geography is too little known to furnish us with any correct account of the mountains. Those of Abyssinia have been estimated to rise as high as the Alps, and the chain of Mount Atlas to equal the Pyrenees: Some of the mountains at the southern extremity of Africa are also supposed to be of equal height.

	Feet.
Peak of Teneriffe	12236
Gross Morne, Isle of Bourbon	9600
Volcano, ditto	7680

In Asia the Altaic chain has summits said to exceed 10,000 feet.

The high table land in the centre of Asia has not been measured. The mountains of Thibet are estimated to rise 25,000 feet. In the Indian Islands there are several mountains which are said to rise from 10 to 13,000 feet.

South America.

Chimborazo,	Quito	—	22,700
Cotopaxi,	ditto	—	20,325
Pic d'Oriziba	—	—	17,368

Many other mountains in the Andes equal or exceed the height of Mont Blanc.

North America.

Some very lofty mountains rise on the western coast; but few of the mountains in the Apalachian chain, or the Allegahny on the eastern side, rise three thousand feet above the level of the sea.

The greatest depth of the sea that it has been practicable to measure is one mile and sixty-six feet. The average depth has been estimated at four miles, but according to La Place it cannot be less than eleven miles. He founds this opinion on the depth of water necessary to raise the tides to a given height.

A VOCABULARY

Containing some of the Terms and Names used in Geology and Mineralogy, which may not be familiar to the general Reader.

The Pages refer to the present volume.——*Prov.* implies that the term is provincial.

Actinolite, (from *aktin,* a ray, and *lithos,* a stone,) called also *Actinote,* a mineral generally radiated, and inclining to a green colour, considered as a species of hornblende.

Adamantine lustre, denotes a lustre of a similar kind to that of pearls, but much more brilliant.

Adularia, a variety of felspar.

Aggregated, united by adhesion, and not by chemical affinity.

Alabaster, p. 213.

Alloys, combinations of different metals with each other.

Alluvial depositions, beds of clay, gravel, &c. formed by water from the destruction of rocks or strata.

Alumine, pure clay, see p. 33.

Alum slate or *Shale,* } a slaty argillaceous stone, from which sulphat of alumine, or alum, is produced.
Aluminous Schistus,

Amethyst, a violet-blue variety of quartz.

Amianth, fibrous asbestus.

Amorphous, without any regular shape, uncrystallized.

Amphibole, a name given by the French to hornblende.

Amygdaloidal, see p. 29.

Anhydrous, not containing water.

Anthracite, a species of hard shining coal which burns without smoke.

Apatite, a stone composed of lime and the phosphoric acid.

Argillaceous, clayey.

Arsenical pyrites, a white splendent combination of arsenic, iron, and sulphur.

Asbestus, a fibrous soft greenish mineral with a pearly lustre, composed of silex, clay, and magnesia.

Asphaltum, a species of bitumen or mineral pitch.

Augite, a blackish green crystallized mineral found in basalt and lava, nearly resembling hornblende.

Barytes, a peculiar heavy earth, having many properties resembling lime and the fixed alkalies.

Basalt, see p. 118.

Basaltic, resembling basalt, either in structure or composition.

Basset, prov. When a stratum rises to the surface, it is said to basset or crop out.

Belland, prov. small particles of lead ore.

Bind, prov. indurated clay.

Bitumen, mineral pitch.

Bituminous, containing bitumen.

Blende, an ore of zinc combined with sulphur.

Borates, salts formed by the boracic acid.

Borax, soda combined with a peculiar acid called the boracic.

Botryoidal, shaped like closely clustered grapes.

Breccia, composed of rounded stones or fragments of rock cemented together into a compact mass, such as pudding-stone.

Brown coal, see p. 105.

Calcareous earth, carbonate of lime, see p. 34.

Calcareous spar, or *Calc-spar*, crystallized carbonate of lime.

Calx, a metallic oxyd, or a metal combined with oxygen by combustion.

Capillary, shaped like hair.

Carbon, the basis of charcoal.

Carbonates, salts formed by the combination of any base with carbonic acid.

Carburets, compound substances containing carbon.

Cawk, prov. sulphat of barytes.

Cellular, see p. 27.

Chalcedony,
Carnelian, } varieties of siliceous stones.

Chalk, p. 210.

Chatoyant, changing colour according to the direction in which the surface receives and reflects light.

Chert, a siliceous stone nearly resembling flint.

Chlorite, a darkish green mineral composed of silex, clay, magnesia, and oxyd of iron.

Chlorite slate, slate formed of chlorite.

Cinnabar, native vermilion, an ore of mercury.

Clavated, like a club.

Clay iron-stone, see p. 190.

Clay porphyry, clay-stone with crystals imbedded.

Clay slate, argillaceous schistus, see p. 102.

Clay stone, a compact stone which passes by gradation from indurated clay to jasper and compact felspar.

Clink-stone, a basaltic stone which yields a metallic sound when struck.

Clunch, prov. slaty indurated clay.

Cobalt, a metal from which smalt and zaffre are made.

Columnar, in columns or prisms.

Combination, the chemical union of two substances, not the mechanical mixture of the parts.

Compact, see p. 27.

Concentric, when in spherical layers over each other.

Conchoidal, see p. 27.

Cotemporaneous veins, seams or fissures in rocks filled with ore or mineral substances which were formed at the same time with the rock, and constitute an original part of it.

Cotemporaneous rock-formations, rocks formed or consolidated at the same time.

Coralloidal, branched like coral.

Cross courses, the veins in a mining district that cut through the regular veins.

Cuneiform, like a wedge.

Decomposition, the separation of the constituent parts of bodies by chemical means.

Decrepitation, the peculiar crackling noise made by salt when thrown upon the fire.

Deliquesce, to dissolve by the moisture of the atmosphere.

Dendritic, like a tree.

Dentiform, shaped like teeth, but applied particularly to the shape of canine teeth.

Dip, the point of the compass to which a stratum inclines.

Docimastic art, the art of assaying metals.

Dog-tooth spar, calcareous crystals consisting of two six-sided pyramids united, whose bases alternately advance and recede in a zigzag form. This form of the crystal is denominated by Haüy *Métatastique*.

Druses, cavities lined with crystals.

Drusy, covered with minute crystals.

Dykes or *Faults*, see chapter XII.

Earths, names of, barytes, strontian, magnesia, lime, silex, alumine, zircon, glucine, ittria.

Efflorescence, the powder formed on some saline substances by exposure to the atmosphere.

Electric, attracting light bodies when rubbed.

Elements, the simple constituent parts of substances.

Epidote, a variety of actinolite.

Fascicular, (scopiform,) composed of a number of needle-shaped crystals which diverge from a common centre.

Felspar, or *Feldspar*, see p. 38.

Felspar, varieties of:

Resplendent
Opalescent
Green
Compact
Decomposed
Adularia
Labradore
Amazon stone
Hornstone
Kaolin and Porcelain earth.

Filiform, in the shape of threads.

Flint, p. 211.

Flinty slate, p. 104.

Flœtz, a barbarous term introduced from the German to denote flat or parallel stratified rocks.

Flocan or *Flucan*, (prov.) a whitish or blueish clayey substance lining veins, and sometimes intermixed with the ore.

Fluor spar, lime combined with fluoric acid.

Flux, a substance mixt with a mineral to promote fusion.

Friable, that will easily crumble in pieces.

Fusion, the rendering of a solid body fluid by the application of heat.

Galena, lead combined with sulphur.

Gangart, the mineral substance in veins in which the ore is generally imbedded.

Garnet, a crystallized stone composed of silex, clay, and iron; the crystals have generally 12 sides whose faces are rhombs.

Gelatinise, a property peculiar to some minerals of forming a kind of jelly when dissolved in acids.

*Geognosy**, *Geology*. Geognosy, as defined by Mr. Jameson, "teaches us the relative position and mode of formation of the mineral masses, of which the crust of the earth is composed." Though the Germans, who delight in multiplying words, affect to make a distinction between geology and geognosy, according to this definition they are synonymous.

Glance, from the German, shining.

Glucine, a peculiar earth, resembling clay in many of its properties; it forms a constituent part of the precious stone called beryl, or aqua marine, and also of the emerald.

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* The term "well educated geognost," as used by some writers, denotes a perfect disciple of Werner, who has lost the use of his own eyes by constantly looking through the eyes of his master.

Gneiss, see p. 80.

Gossan, (prov.) a friable ferrugineous substance found near the upper part of metallic veins in Cornwall.

Granite, see p. 65.

Granitic, see p. 28.

Granular, see p. 27.

Gray wacke, see p. 105.

Green stone, see p. 118.

Growan, a name used by Cornish miners for granite.

Gypsum, *Gyps*, lime combined with sulphuric acid.

Hanger and *Ledger*, (prov.) the upper and under side of a vein.

Heavy spar, barytes.

Heliotrope, a siliceous stone, generally spotted green and red.

Hematite, a particular ore of iron.

Hornblende, see p. 41.

Horn-stone, a siliceous stone, chert.

Horn-ore, corneous silver ore, or muriat of silver.

Hydrat, a salt or mineral substance combined with water.

Hydrogen gas, inflammable air.

Jasper, is composed of silex and clay,

Integrant particle, the minutest particle of a compound body which can be supposed to exist without separating the different elementary particles of which it is composed.

Intumescent, boiling and swelling in the fire like alum.

Iridescent, coloured like the rainbow.

Iron-stone, see p. 190.

Ittrya, a peculiar earth, found in a mineral substance at Ytterby, by Dr. Gadolin, hence called by some mineralogists Gadolinite.

Killas, (prov.) a schistous rock nearly allied to slate.

Lamellar, consisting of plates.

Laminæ, thin leaves.
Lava, see p. 329.
Lenticular, shaped like a double convex lens.
Leucite, a mineral found in lava, which resembles garnet in its crystallization, but contains potass.
Lias, (prov.) see Appendix, p. 470.
Lime, see p. 34.
Lode, (prov.) a metallic vein.

Magnesia, see p. 35.
Magnetic, which attracts iron.
Malachite, green carbonate of copper.
Mammillary, with a number of convex smooth surfaces.
Mandelstein, a name given by the Germans to amygdaloid.
Marl, generally composed of clay, silex, and lime.
Marle, a twin crystal, or two crystals crossing each other.
Matrix, the substance in which metallic ores are imbedded.
Mechanical depositions, beds or strata formed by the deposition of substances suspended or carried by water.
Metals, names and situations of, 299.
Metallic oxyds, combinations of metals with oxygen.
Metallic bases, salts formed of metals combined with acids are said to have metallic bases.
Metalliferous, containing metals.
Mica, see p. 40.
Micaceous schist, or *Mica slate*, see p. 82.
Molecules, the ultimate particles of bodies.
Mud, volcanic, p. 334.

Nacry, and *Nacreous*, having the pearly lustre of shells.
Naphtha, a light mineral oil.
Native metals, such as are found in nature in a metallic state.
Natron, a name for native carbonate of soda.
Nickel, a peculiar metal, which like iron is attracted by the magnet.
Nodulous or *Tuberous*, having protuberances like a potatoe.

Obsidian, volcanic glass, see p. 332.

Ochres, combinations of the earths with oxyd or carbonate of iron.

Olivine, an olive-coloured mineral found in basalt.

Oölite, roe-stone, see p. 208.

Opalescent, transmitting variously coloured light combined with a milky cloudiness, as in the siliceous stone called Opal.

Ores, metallic matter combined with extraneous substances.

Oxygen, a substance hitherto undecomposed, which united with hydrogen forms water; with some combustible substances it forms acids. Substances combined with oxygen, but not acidified, are called oxyds.

Peat, see p. 257.

Pearl-spar, a sparry iron-ore, a carbonate of iron having a pearly lustre.

Pearl-stone, pearly-coloured obsidian.

Phosphorescent, luminous in the dark.

Pitch-stone, a hard brittle siliceous stone resembling pitch in its lustre and appearance.

Plumbago, black lead, graphite, composed of carbon and a small quantity of iron.

Porphyry, see p. 119.

Pot-stone, a variety of serpentine from which vessels are formed.

Primitive lime-stone, crystalline marble, p. 72.

Pumice, see p. 330.

Puzzolana, see p. 335.

Pyrites, combinations of metals with sulphur, which have a metallic lustre.

Quartz, see p. 36.

Quartz, principal varieties of:

Colourless and Crystallized	Rock crystal
Purple do. — —	Amethyst

Blue quartz — — False Sapphire
Green do. — — Prase
Yellow do. — — False topaz
Red do. — — — { Rose quartz / Milk quartz }
Chatoyant — — — Cat's-eye
Smoke quartz — — Cairngorum stone
Rainbow quartz — Avanturine
Translucent amorphous
Milky white — — Chalcedony
Various — — — Agate
Ditto — — — Carnelian
With parallel layers of different colours — { Onyx / Sardonyx }
Green and red — — Heliotrope
Apple green — — Chrysoprase
Opalescent — — Opal
Imperfectly opalescent — Semiopal
Opalescent in water — Hydrophane
Various — — — Flint
Opaque
Red — — — Sinople
Gray — — — Chert.

Quartzose, principally composed of quartz.

Reddle, red iron ochre.

Reniform, kidney-shaped.

Rider, a stony mass dividing a metallic vein.

Rock crystal, crystallized silex.

Roe-stone, oölite, calcareous stone with globules imbedded, supposed to resemble the roes of fishes.

Ruby, a precious stone composed principally of crystallized clay.

Sand-stone, red sand-stone, see p. 62.

Sapphire, see note p. 34.

Sattin spar, fibrous carbonate of lime, which is white and has a pearly lustre.

Schiller spar, crystallized serpentine.

Schorl, a velvet-black mineral crystallized in long slender prisms aggregated or disseminated in rocks. The tourmaline is a species of schorl: it becomes electric by heat.

Scopiform, diverging like the sticks of an open fan.

Sectile, that may be cut without breaking, but not malleable.

Selenite, crystallized gypsum.

Serpentine, see p. 90.

Shaft, (prov.) the well or entrance into a mine.

Shale, slaty argillaceous stone.

Sienite, see p. 117.

Silex, see p. 33.

Smaragdite, a greenish mineral nearly allied to serpentine, by some mineralogists called diallage.

Spar or *Spath,* a name for crystallized minerals.

Spathose or *Sparry,* composed of irregular crystalline parts.

Specular, having a polished surface.

Stalactites, calcareous depositions formed on the roofs of caverns, &c.

Stalagmites, calcareous depositions formed on the floors of caverns.

Steatite or *Soap rock,* a soapy-feeling stone, composed of magnesia, silex, and clay.

Stratum, see p. 29.

Strontian, a peculiar earth, first found at Strontian in Scotland.

Subcrystalline, imperfectly crystallized.

Swine-stone, a peculiar lime-stone which yields a fœtid smell when broken.

Tabular, of an equal thickness, but long and broad compared with the depth.

Talc, see p. 40.

Talcous slate, slate containing talc.

Testaceous, in curved layers.

Topaz, a precious stone composed of silex, clay, iron, and fluoric acid.

Topaz-rock, a granitic rock containing crystals of topaz.

Tourmaline, see *Schorl*.

Transition rocks, see chap. V.

Translucent, admitting the transmission of light.

Transparent, through which the forms of objects can be seen.

Trap, see p. 118.

Trapezoidal, having six unequal faces, each terminated by four unequal lines.

Tubular, cylindrical and hollow.

Veins, metallic, see p. 274.

Vesuvian, a peculiar mineral found in the rocks near Vesuvius.

Unctuous, having a soapy feel; a quality peculiar to some minerals generally containing magnesia.

Wacke, an earthy kind of basalt. It is necessary to observe that this is a different mineral from the gray wacke.

Whin-stone, a name used in the north part of England and in Scotland, for Basalt and Green stone: but any hard dark-coloured stone is also frequently called Whin-stone by the miners.

Zeolite, a mineral found in basaltic rocks, which intumesces when heated, and is converted into a jelly by solution in acids: the colour is generally white, and the lustre pearly.

Principal varieties of Zeolite, with the names given by Haüy.

Radiated — — Mesotype
Foliated and nacry — Stilbite
Mealy — — — Laumonite
Cubic — — — { Analcime / Chabasie.

Zircon, a peculiar earth; also a precious stone principally composed of this earth.

Those who are desirous of inspecting the rare productions of the mineral kingdom may have the opportunity of seeing the very valuable and well-arranged collection at the British Museum.—A great variety of minerals from different parts of the world are kept for sale by Messrs. Brown and Mawe, 149 Strand, London.

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